# Graduate Student Researchers Program 2000

## Program Solicitation Handbook

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# Introduction

Since 1980, the National Aeronautics and Space Administration has sponsored the NASA Graduate Student Researchers Program (GSRP) to help meet the continuing needs of the aeronautics and space effort by increasing the number of highly trained scientists and engineers in aerospace, space, Earth, and life sciences, space applications, and space technology.

The NASA Graduate Student Researchers Program (GSRP) awards fellowships for graduate study leading to research-based masters or doctoral degrees in the fields of science, mathematics, and engineering.

This program book and website provides information about eligibility, submission of proposals, and the application process. We hope that you will spend a few minutes exploring the opportunity to both continue your graduate education and participate in the exciting world of NASA.

# NASA Strategic Enterprises, Centers, and Facilities

NASA employs 18,500 civil servants and generates thousands of high-tech jobs in the private sector. The Agency operates nine Field Centers, the contractor-operated Jet Propulsion Laboratory, and the Wallops Flight Facility nationwide.

NASA's overall program, as outlined in the agency's Strategic Plan (see the NASA web site for additional information: www.nasa.gov), is comprised of four Strategic Enterprises. Each enterprise covers a major area of the agency's research and development efforts. The four NASA enterprises are:

Aero-Space Technology--The mission of this Enterprise is to pioneer the identification, development, verification, transfer, application and commercialization of high-payoff aeronautics andspace transportation technologies. The Enterprise is managed by the Headquarters Office of Aero-Space Technology.

Earth Science--The mission of this Enterprise, formerly the Mission to Planet Earth Enterprise, is to use the unique vantage point of space to provide information about Earth's environment that is obtainable in no other way. In concert with research and industry partners, the Enterprise is developing the understanding needed to support the complex environmental policy and economic investment decisions that lie ahead. The Office of Earth Science manages the Earth Science Enterprise.

Human Exploration and Development of Space--The mission of the HEDS Enterprise is to open the space frontier by exploring, using and enabling the development of space and to expand the human experience into the far reaches of space. The enterprise is managed jointly by the Office of Space Flight and the Office of Life and Microgravity Sciences and Applications.

Space Science--The mission of the Space Science Enterprise is to solve mysteries of the universe, explore the solar system, discover planets around other stars, search for life beyond Earth from origins to destiny, chart the evolution of the universe and understand its galaxies, stars, planets, and life. The Space Science enterprise is managed by the Office of Space Science.

Specific information about the NASA field centers can be obtained from the NASA web site (www.nasa.gov) and research opportunities at each center are found in this text. See table of contents.

# Graduate Student Researchers Program Background

In 1980, NASA initiated the Graduate Student Researchers Program. The purposes of GSRP are to cultivate additional research ties to the academic community and broaden the base of students pursuing advanced degrees in science and engineering.

Fellowships are awarded for graduate study leading to research-based masters or doctoral degrees in the fields of science, mathematics, and engineering. Grants of up to $22,000 are awarded for one year and are renewable for a total of three years based on satisfactory academic advancement, research progress, and available funding. Approximately 300 graduate students are supported by this program each year. Students may apply prior to receiving their baccalaureate degree or at any time during their graduate career. An applicant must be sponsored by a faculty advisor or his/her graduate department chair. Awardees may not simultaneously accept any other Federal fellowships or traineeships. However, under Section 178(a) of Title 38, U.S. Code, educational benefits from the Department of Veterans Affairs may be received at the same time. Upon completion of the research required by the fellowship program there is no formal obligation for service to the Federal government.

Each year approximately 90 new awardees are selected based on competitive evaluation of their proposal and academic qualifications. Usually 40 of the new awards are sponsored by NASA Headquarters through the Office of Space Science (OSS), the Office of Life and Microgravity Sciences and Applications (OLMSA), and the Office of Earth Science (OES).

NASA's discipline scientists competitively evaluate students and their proposals based upon the student’s academic qualifications, proposed research, and plan of study. Fellows selected by NASA Headquarters conduct research at their respective universities. The remaining awards are distributed through the nine NASA Field Centers and the Jet Propulsion Laboratory, each of which has specific research programs and facilities. Fellows selected by Centers must spend some period of time in residence at the Center, taking advantage of the unique research facilities of the installation and working with Center personnel. The projected use of Center expertise and facilities is an important factor in the selection of Center fellows.

## General Policies & Procedures

### Submission of New Proposal

All applicants must submit one original and five (5) copies of all materials **by February 1, 2000**, to the appropriate NASA facility from which consideration is being requested. Submissions should be addressed to the attention of the appropriate Program Administrator listed on page 11 of this brochure. See page 9 for new proposal requirements.

Applications will be reviewed and selections made in early May 2000. Proposed starting dates for new awards are the first day of July, August, or September, 2000.

**Submission of a Renewal Proposal**

Proposals for renewal (year 2 or year 3 in the program) are to be submitted to the appropriate HQ or center address by the **February 1, 2000**. All renewal applicants should submit an original and five (5) copies of all requested materials. The renewal proposal must include:

a) signed original proposal cover sheet;
b) budget page;
c) university certifications;
d) a statement (approximately one to two pages) by the student outlining his or her progress on the research or plan of study;
e) transcript of the student's grades during the preceding year; and
f) a one-page evaluation and recommendation for renewal signed by the faculty advisor.

Renewals are not automatic. Incomplete or late proposals will not be renewed. The starting date for renewals will be the anniversary of the original grant.

**Selection of Proposals**

Graduate students are selected for participation in this program by NASA Headquarters, individual NASA Field Centers, or by the Jet Propulsion Laboratory. Selection is based on:

1. the quality of the proposed research or plan of study and its relevance to NASA programs;
2. student academic qualifications;
3. the ability of the student to accomplish the defined research;
   and,
   **For Center Applicants;**
4. the proposed utilization of Center research facilities.

**Awards**

Fellowships are awarded as training grants and are made for a period of one year and may be renewed annually for a total of three years. Fellowship renewal is based on satisfactory progress as reflected in performance evaluations. Renewals must also be approved by the Program Administrator and Technical Advisor at the appropriate NASA Field Center or NASA Headquarters.

## Eligibility

All applicants must be full-time graduate students enrolled in an accredited U.S. college or university. Applicants must be citizens of the U.S. and may apply to the program prior to receiving their baccalaureate degrees or any time during their graduate work. Students who apply prior to acceptance in graduate school must submit a list of prospective schools and if selected must provide proof of acceptance prior to an award. All applications must be sponsored by a faculty advisor or the student's graduate department chair. An individual accepting this award may not concurrently receive other Federal fellowships or traineeships. African Americans, Native Americans, Mexican Americans, Puerto Ricans, Alaskan Natives, Native Pacific Islanders, women, and persons with disabilities are strongly urged to apply.

## Equal Opportunity

No applicant shall be denied consideration or appointment as a NASA Graduate Student Researcher on the grounds of race, creed, color, national origin, age, sex or disability.

## Equipment

GSRP grant funds cannot be used for the purchase of any equipment including computers.

## Funding

The total annual award per graduate student cannot exceed $22,000. This amount includes a $16,000 (maximum) student stipend and an allowance of up to $6,000--$3,000 for student expenses and $3,000 for university expenses. The student allowance may be used to help defray tuition costs, purchase books and software, or to provide per diem and travel for the student. It may also be used to help defray living expenses during periods of Center residency, if applicable.

The university allowance may also be used for tuition or to support research-related travel for the faculty advisor or the student. Alternative uses for this allowance may be requested but must be consistent with the intent of the program.

## Disposition of Unused Funds

If a student ends the GSRP earlier than anticipated, the student stipend is prorated and terminated. Refer to section below concerning replacement students for information on unused funds. Renewal applicants who have funds remaining from their previous year's budget may carry the remaining funds over into the following program year.

## Obligation to the Government

A student receiving support under the Graduate Student Researchers Program does not incur any formal obligation to the Government of the United States. The objectives of this program will be served best if the student actively pursues research, teaching, or employment in aeronautics, space science, or space technology after completion of graduate studies.

## Replacement Students

If a student withdraws **within the first half of the award year**, the award will be prorated and the remaining funds returned to NASA. If a student discontinues participation in the program after the first six months of the award period, the university may nominate another student with similar achievement and research objectives to complete the remaining months of the current award year.

Documentation required for nomination of replacement students must include: a) a written statement by the original student giving the date and reason for withdrawal from the program; b) a proposal cover sheet signed by the replacement student and faculty advisor; and c) a brief description of the student's research and educational background, on university letter head. If the nominated replacement student is approved, an amendment to the grant will be issued. Replacement students must be approved by the appropriate NASA Grants Office.

Replacement students electing to apply to the GSRP for the following program year are subject to the evaluation and selection procedures administered to new applicants. Replacement students selected as new applicants will be eligible for up to three full years of support, depending upon satisfactory progress and available funding.

## Foreign Travel

All foreign travel, charged to the grant, must have prior approval of the appropriate GSRP Administrator and NASA Grants Officer and must clearly be relevant to the research effort. For each foreign trip, the student or advisor must submit a written request on university letterhead stating the purpose, costs, travel dates, and the NASA fellowship number.

Requests should be made two (2) months prior to the proposed travel. Requests that are submitted after the travel has been completed will be denied.

## Internal Revenue Service

All questions concerning taxes should be directed to the Internal Revenue Service. Refer to IRS Publication 520 titled "Scholarships and Fellowships", and Publication 508 titled "Educational Expenses".

## Inquiries

Questions concerning the preparation and submission of proposals and the administration of this program are to be directed to the appropriate Program Administrator. Policy questions should be directed to the National Program Manager.

## Final Administrative Report

It is the responsibility of the institution receiving a NASA GSRP award to ensure that the final report on the fellow's research and academic progress is submitted. This report is due no later than 90 days after the termination date of the award. The report must include: a) the degree granted; b) important results of the student experiences (e.g., thesis title, papers published other than thesis, presentations made, awards, honors); and c) employment or other future plans. This report should be submitted to the appropriate NASA Center or Headquarters GSRP Administrator, and the relevant grants office.

# Preparation of Proposal

## Proposal Requirements

All applicants must submit one original and five (5) copies of all materials by **February 1, 2000**, to each Center/Program Office for which consideration is sought. See page 11 for contact information.

**Proposals for the GSRP must be written by the student**. To ensure the preparation of a competitive proposal, students are strongly encouraged to collaborate with a faculty member and with a potential NASA Technical Advisor to identify a project. Students are advised to enlist the aid of their faculty advisor for guidance, review, and commentary on the written material prior to submission.

At least one (1) complete proposal package must contain original signatures. Proposals must be assembled in the following order. See page 189 for proposal cover sheet and certifications.

1) Original Signed Proposal Cover Sheet
2) Abstract (100 words)
3) Budget
4) Description of Proposed Research and/or Plan of Study
5) Letter of Recommendation
6) Personnel
7) Certifications
8) Planned Use of Facilities and Resources (Center Applications Only)

The original and all copies of proposals must be stapled. To facilitate the recycling of proposals after review, proposals should be submitted on plain, white paper only. Do not use cardboard stock, plastic covers, spiral binders, colored paper, etc.

**1. Proposal Cover Sheet**
The proposal cover sheet must be filled out and signed by the student, faculty advisor, and university official responsible for committing the institution for sponsored research. Proposals will not be funded without the required university approval signatures.

**2. Abstract**
Proposal abstracts should concisely detail the intended research and its relationship to the NASA mission. The abstract should not exceed 100 words.

**3. Budget**
Budget must include the following: (a) student stipend—up to $16,000 basic stipend for twelve months; (b) student allowance—$3,000. The student allowance can include cost estimates for tuition expenses and/or anticipated travel and living expenses for the student at a NASA facility; and (c) university allowance—$3,000. The university allowance can

include cost estimates for travel of faculty advisor or other expenses that relate to the student's research project. Student tuition may also be charged against this allowance. The budget must be prorated when the student anticipates less than a 12 month program tenure.

**4. Description of Proposed Research and/or Plan of Study**
Students must prepare a typed, detailed research proposal (not to exceed five single-spaced pages). At a minimum, this critical document must contain a research plan, study objectives, schedule, methodology, key elements, and milestones.

**The research proposal must be signed by the student and the advisor with an indication of the level of assistance provided by the advisor. Remember, GSRP proposals must be written by the student.**

**5. Letter of Recommendation**
The faculty advisor must prepare and sign a one-page letter of recommendation on behalf of the student. Included in this letter must be a statement indicating the level of assistance provided to the student in the preparation of the GSRP proposal.

**6. Personnel**
The faculty advisor must submit a short biographical sketch that includes name, current position, title, department, university address, phone number, and principal publications. The student is required to submit a transcript of all university activities (graduate and undergraduate) along with a summary of special training, previous research projects, awards, scholarships, and significant accomplishments.

**7. Certifications**
All application packages must include university certifications to debarment and suspension and drug-free workplace.

**8. Facilities and Resources (Center Applicants Only)**
Students competing for center awards must indicate the NASA facilities and resources to be used in support of the research and/or plan of study, including an estimate of any computer time required. Students are strongly encouraged to contact the appropriate NASA Technical Advisor to coordinate research activities.

# Program Administration

The NASA Graduate Student Researchers Program (GSRP) is offered by the NASA Headquarters Education Division, Office of Human Resources and Education, and is managed at the national level by:

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NASA Headquarters Program Offices and each NASA Field Center and the Jet Propulsion Laboratory administers its own GSRP program under the direction of the following officials. <u>Please direct proposals and inquiries to these individuals:</u>

## NASA Headquarters

**Ms. Dolores Holland**
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**Ms. Debra Spears**
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debra.spears@hq.nasa.gov

**Ms. Anne N. Crouch**
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NASA Headquarters
300 E Street, SW
Washington, DC 20546
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## Ames Research Center

**Ms. Meredith Moore**
Mail Stop 241-3
NASA Ames Research Center
Moffett Field, CA 94035
(650) 604-5624
Email address: mmoore@mail.arc.nasa.gov

## Hugh L. Dryden Flight Research Center

**Dr. Kajal K. Gupta**
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## John H. Glenn Research Center at Lewis Field

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## Goddard Space Flight Center

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gsoffen@pop100.gsfc.nasa.gov

## Jet Propulsion Laboratory

**Ms. Carol S. Hix**
Educational Affairs Office
Mail Stop 180-109
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## Lyndon B. Johnson Space Center

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## John F. Kennedy Space Center

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## Langley Research Center

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## George C. Marshall Space Flight Center

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## John C. Stennis Space Center

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# Disciplines at NASA Centers

The following chart depicts awardee disciplines during the 1999 program year by NASA Field Center and Headquarters. This is not an exclusive indication of the disciplines supported but a quick reference to the array of academic areas that are associated with each program component.

## 1999 Research Areas

| | HQS | HQU | HQY | ARC | DFRC | GRC | GSFC | KSC | JPL | JSC | LaRC | MSFC | SSC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Aeronautical | X | X | - | X | X | X | X | X | - | - | X | X | - |
| Chemical | - | X | - | X | X | X | - | X | X | - | - | - | X |
| Electrical | X | - | X | - | X | X | X | X | X | - | X | - | X |
| Mechanical | - | X | - | - | X | X | X | X | - | X | X | X | X |
| Mettalurgy/ Materials | - | - | - | X | - | X | - | - | - | - | X | X | - |
| Eng, NEC | - | X | X | X | X | X | X | X | X | X | X | X | X |
| Astronomy | X | - | - | X | - | - | X | - | X | - | - | - | - |
| Chemistry | X | - | X | X | - | X | - | - | X | - | X | - | - |
| Physics | X | X | - | X | - | X | X | X | X | - | X | X | X |
| Physical Sc, NEC | X | X | X | X | - | - | X | - | X | - | - | X | - |
| Mathematics | - | X | - | X | - | - | - | X | - | - | X | - | - |
| Computer Sc. | X | - | - | X | - | X | - | X | X | X | - | - | X |
| Math/Comp, NEC | X | - | - | X | - | X | X | X | X | - | - | - | - |
| Biological Science | X | X | - | X | - | - | - | X | - | - | - | - | X |
| Life Sc, NEC | - | X | - | X | - | - | - | X | X | X | - | - | X |
| Social Sc. | - | - | - | X | - | - | - | - | - | - | - | X | - |
| Atm. Sc. | X | - | X | X | - | - | X | - | - | - | - | X | - |
| Geol Sc. | X | - | - | X | - | - | X | - | X | - | - | - | - |
| Oceanography | - | - | X | - | - | - | X | - | X | - | - | - | X |
| Environ Sc. | - | X | X | X | - | - | X | - | - | - | - | X | X |
| Psych, NEC | - | X | - | X | - | - | - | - | - | - | X | - | - |
| Other Sciences | X | X | X | X | - | X | X | X | X | X | X | X | X |

*NEC: Not Elsewhere Classified

# Office of Space Science

The NASA Headquarters Office of Space Science (OSS) supports basic and applied research in space science. The OSS research program includes the development of major space flight missions such as the Chandra X-Ray Observatory and the Cassini Mission to Saturn, complementary laboratory research and analysis of data from prior missions, and theoretical studies.

Program Administrator:
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Mail Office of Space Science proposals to:
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Washington, DC 20024

The fundamental questions and goals for Space Science are described in The Space Science Enterprise Strategic Plan, which can be accessed at http://www.hq.nasa.gov/office/oss/strategy/. Proposers are reminded that a key criterion for proposal evaluation is the relevance of the proposed investigation to the NASA mission, as described in the science theme roadmaps in the Strategic Plan.

Within the Office of Space Science, activities are organized into four major theme areas. A brief description of these themes follows:

- **Structure and Evolution of the Universe —** addressees cosmology, large scale structure of the universe, evolution of stars and galaxies, including the Milky Way and objects with extreme physical conditions. Questions of interest are: What is the universe? How did it come into being? How does it work? What is its ultimate fate?
- **Astronomical Search for Origins and Planetary Systems —** addresses the origins of galaxies, stars, protoplanetary disks, extra-solar planetary systems, Earth-like planets and the origin of life. Questions of interest are: How were galaxies born? How do stars and solar systems form? Are there other Earth-like planets?
- **Solar System Exploration —** addresses scientific activities that pertain to the solar system, including comets, and major and minor planets. Questions of interest are: What are the origin of the Sun, the Earth, and the planets, and how did they evolve? Did life evolve on other planetary bodies in the solar system? Are there worlds

around other stars? What are the ultimate fates of planetary systems? What threat is posed by the potential for collisions with Earth-approaching objects?

- **The Sun-Earth Connection —** addresses the sphere of influence of the Sun on the Earth environment. Questions of interest are: What causes solar variability? How does the sun and its variability affect the Earth and other planets?

**Structure and Evolution of the Universe —** Research in this theme is focused into six campaigns targeted towards identification of dark matter and its influence on the shape of galaxies and clusters of galaxies; finding out where and when chemical elements were made; understanding of the cycles in which matter, energy, and magnetic field are exchanged between stars and interstellar gas; discovery of how gas flows in disks and formation of cosmic jets; identification of sources of gamma-ray bursts and high-energy cosmic rays; measurement of strong gravity near black holes and its affects on the early Universe. Emphasis is placed on the development and implementation of a multi-wavelength program of space-based and suborbital missions (airborne, sounding rockets, balloons). Investigations that support instrumentation development relevant to future missions in the above areas, the analysis of data from ongoing and past missions, and laboratory and theoretical investigations that support the interpretation of relevant space-based observations are invited. Individuals are strongly encouraged to make their proposals directly relevant to the missions of this theme. In particular, recent successful proposals have concentrated on developing hardware or modeling tools and carrying out essential observations, specifically for particular NASA-supported missions.

**Astronomical Search for Origins and Planetary Systems —** Research in Origins is directed toward a greater understanding of the origin of galaxies, stars, solar systems, and life. Emphasis is placed on the development and implementation of a multi-wavelength program of space-based and suborbital missions (airborne, sounding rockets, balloons). Programs are encouraged that support instrumentation development relevant to future missions, the analysis of data from ongoing and past missions, and on laboratory and theoretical investigations that aid in the interpretation of space-based observations. Individuals are strongly encouraged to make their proposals directly relevant to the missions of this theme. In particular, recent successful proposals have concentrated on developing hardware or modeling tools and carrying out essential observations, specifically for particular NASA-supported missions.

**Solar System Exploration —** Solar system research focuses on the origin, evolution, and current state of the various bodies in the solar system, including their interiors, surfaces, and atmospheres and the origin, evolution, and distribution of life in the solar system. Research that exploits analysis of data collected by spacecraft borne instruments, relevant ground-based data and laboratory experiments, and theoretical modeling is solicited. The proposal should present a well-defined problem and justification of its scientific significance, as well as a detailed approach for its solution. Acceptable research topics include studies of the planets, rings, moons, comets, asteroids, meteors and cosmic dust. Areas of research interest include planetary geology and geophysics, materials and geochemistry, exobiology, planetary atmospheres, planetary astronomy, and planetary system science.

**The Sun-Earth Connection —** Research in the Sun-Earth Connections theme focuses on investigations of the Sun, both as a nearby star and as a source of variable outputs of solar wind, energetic particles, and electromagnetic radiations with influence on the Earth and its space environment, on planetary and cometary magnetospheres, and on the heliosphere, and on the local interstellar medium. The program involves investigations of the origin, evolution, and physics of plasmas, electromagnetic fields, and energetic particles in space. Studies of the terrestrial space environment include investigations of the coupling between the variable Sun and the Earth's magnetosphere, ionosphere, thermosphere, and mesosphere. Measurements are made from balloons, rockets, satellites, and deep space probes. Theory and computer simulations are also supported.

Solar activity and the consequential effects of today's technological systems is on the rise from the present solar cycle minimum toward solar maximum in 2000-2001. A unique fleet of spacecraft from the International Solar Terrestrial Physics program are poised to record and track, and research will understand, these Earth-impacting events.

Office of Space Science opportunities offered in Information Systems, are as follows:

**Information Systems —** Information Systems research applies new developments in computer science and information technology to benefit space science endeavors. This includes a broad range of areas, including: science data management and archiving; software technology; data analysis, mining, and exploration; computational methods and algorithms; modeling, simulation and design; knowledge management and synthesis; collaborative environments; and autonomous systems.

# Office of Life and Microgravity Sciences and Applications

**PROGRAM ADMINISTRATOR**

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Mail OLMSA proposals (including express mail, commercial delivery, or courier) to:
Graduate Student Researchers Program
Attn: Ms. Kathleen Wilson
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Proposals sent by express mail, commercial delivery, or courier to:
Graduate Student Researchers Program
Code UP
ATTN: Receiving and Inspection
NASA Headquarters
300 E Street, SW
Washington, DC 20024-3210

## Microgravity Research

The Microgravity Research Division (MRD) conducts a program of physical sciences and process research within the Human Exploration and Development of Space strategic enterprise of NASA. This research is managed within five disciplines: Biotechnology, Combustion Science, Fluid Physics, Fundamental Physics, and Materials Science. Research sponsored by MRD uses the unique attributes of the space environment to advance scientific knowledge and technology, and uses advances in scientific knowledge to better understand the performance of technologies in the unique environment of space. The program includes ground-based research, predominantly conducted within colleges and universities, advanced technology development activities, and flight investigations conducted aboard the Space Shuttle in 2000, aboard the International Space Station.

## Life Sciences

The Life Sciences Division is a multidisciplinary research and technology program in the biomedical and biological sciences. Research focuses on: gravitational biology and ecology, biomedical research and counter-measures; and advanced human support technologies. (see: http://hq.nasa.gov/office/olmsa/lifesci/overview.html). The program includes ground-based research and technology development and flight investigations conducted aboard the Space Shuttle and aboard the International Space Station.

# Office of Earth Science

## PROGRAM ADMINISTRATOR

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## Program Description

Using the unique vantage points from space, aircraft, and *in situ* platforms, NASA's Earth Science Enterprise (ESE) is dedicated to understanding the total Earth system and the effects of natural and human-induced changes on the global environment. ESE supports basic and applied research in the following areas:

- **Biology and Biogeochemistry of Ecosystems and the Global Carbon Cycle —** Will the earth provide food, clean water and renewable resources to support human civilization in the future, and how will human actions affect this ability?

  - How do ecosystems respond to and affect global environmental change?
  - How are land cover and land use changing? What are the causes and consequences?
  - What is the role of ecosystems in the global carbon cycle and might this role change in the future?

- **Global Water and Energy Cycle —** Will the earth provide adequate water resources for human civilization in the future?

  - Is the cycling of water through the atmosphere accelerating?
  - To what extent are variations in local weather, precipitation and water resources related to global climate change?
  - How can the integrated effect of fast atmospheric, land and ocean surface processes be accurately included in large-scale climate models?

- **Climate Variability and Prediction —** Can we expect climate changes of consequence in the next decades and century, and what will be the causes of such changes?

    - Can current global climate variations be understood and predicted?
    - Can observed global climate trends be attributed to specific factors?
    - Can change in polar ice sheets seriously affect global sea level?

- **Atmospheric Chemistry —** How do emissions from human activities affect the atmosphere and quality of air?

    - How will stratospheric ozone respond to reduction in atmospheric abundances of ozone-destroying industrial chemicals?
    - How does the chemistry of atmospheric trace constituents respond to and affect climate?
    - What are the effects of regional pollution on the global atmosphere and the effects of chemical changes on regional air quality?

- **Solid Earth Science —** How can knowledge of the earth's motions be used to provide warning of earthquakes, volcanic eruptions and other natural hazards?

    - What are the motions of the Earth and the Earth's interior, and what information can be inferred about Earth's internal processes?
    - How is the Earth's surface being transformed and how can such information be used to predict future changes?

The Earth System Science (ESS) Fellowship Program funds both Master and Ph.D. applicants pursuing their graduate studies in the field of Earth system science. The financial support for the ESS Fellowships comes from both the Earth science portion of NASA's Graduate Student Researchers Program (GSRP) provided by the NASA Education Division, and the Graduate Student Fellowship in Global Change Research provided by the Office of Earth Science.

Applications are considered for research in atmospheric chemistry and physics, ocean biology and physics, ecosystem dynamics, hydrology, cryospheric processes, geology, geophysics, and information science and engineering, provided that the specific research topic is relevant to NASA's Earth remote sensing science, process studies, modeling and analysis in support of the U.S. Global Change Research Program (USGCRP). NASA discourages submission of paleo-climate related applications to this program. Additional information about the ESE and the Earth Observing System (EOS) scientific priorities can be obtained from the ESE Strategic Plan http://www.earth.nasa.gov/ and EOS science publications http://eospso.gsfc.nasa.gov/eos_homepage/scipubs.html.

Students admitted to or already enrolled in a full-time M.Sc. and/or Ph.D. program at accredited U.S. universities are eligible to apply. Students may enter the program at any time during their graduate work. Students may also apply in their senior year prior to receiving their baccalaureate degree, but must be admitted and enrolled in a M.Sc. and/or Ph.D. program at a U.S. university at the time of the award. United States citizens and resident aliens will be given preference, although the program is not restricted to them. Students with disabilities and from underrepresented minority groups are urged to apply. No applicant shall be denied consideration or appointment as a NASA Earth System Science Fellow on grounds of race, creed, color, national origin, age, or sex.

The announcement for ESS Fellowship applications is made in mid December each year, with proposals due in mid March and selections made at the end of June of the following year. The announcement, including a detailed description of the submission procedure, is available under “Research Opportunities” at http://www.earth.nasa.gov/.

# Ames Research Center

## MISSION

Ames is the NASA designated Center of Excellence for Information Technology and has Agency lead mission responsibility for Aviation Operations Systems and Astrobiology. Ames Research Center also has Lead Center program roles in Aviation System Capacity, Rotorcraft Technology, High Performance Computing and Communications, Gravitational Biology and Ecology, Supercomputer Consolidation, Simulators and Aeronautics Computers. Ames is home to three national wind tunnel complexes, including the world's largest; several advanced flight simulators; a variety of supercomputers, including some of the world's fastest; a suite of centrifuges that serve as a national resource; and several unique aircraft used for rotorcraft flight research and as flying scientific laboratories. Ames has a wide variety of other facilities for life, earth and space science research.

The Ames Research Center conducts research activities, technology programs, and flight projects that advance the nation's capabilities in civilian and military aeronautics, space sciences, and space applications. This diverse program at Ames is organized into aerospace, information sciences and technology, and astrobiology and space research.

In preparing a proposal for a fellowship at Ames Research Center, prior collaboration with an Ames researcher is mandatory. A suggested point of contact is listed with each research topic for which a student may apply.

### PROGRAM ADMINISTRATOR

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mmoore@mail.arc.nasa.gov

# AEROSPACE

## AEROSPACE TECHNOLOGY

In aerospace, Ames concentrates on rotorcraft and powered lift aircraft technology, fluid mechanics, experimental aerodynamics, flight simulation, flight systems research advanced air traffic management system, and space transportation technologies.

**Michael Dudley**
(650) 604-5046
mdudley@mail.arc.nasa.gov

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**Air Traffic Management —** Projected demands on the Nation's air transportation system necessitate continued research to develop information systems and automation that will provide increased system capacity while maintaining safety. NASA is working to develop technology for the FAA and airspace users that enables more efficient air traffic management by predicting aircraft positions and conflicts so automated advisories can be generated to optimize schedules and resolve conflicts. The research also emphasizes human factors and advance display development to facilitate the human/automation systems interfaces.

**Heinz Erzberger**
(650) 604-5425
herzberger@mail.arc.nasa.gov

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**Computer Vision —** Computer vision and image understanding techniques are being applied to the navigation of rotorcraft and aircraft during low-altitude flight, landing and taxing. The techniques are quite general and can be used in the autonomous guidance of other types of vehicles including general aviation aircraft and large transports.

**Banavar Sridhar**
(650) 604-5450
bsridhar@mail.arc.nasa.gov

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**High Performance Computing and Communications (HPCC)/Computational Aerosciences Project —** Current advances in high performance computing are coming from novel computer architectures such as parallel processors, vector processors, and heterogeneous networks of computers. The suitability of these architectures to solving problems of interest to NASA and the development of new architectures that efficiently solve these problems is the objective of this research. Of particular interest is the investigation of architectures to solve problems arising in computational fluid dynamics as governed by the Navier Stokes equations. These investigations could include software issues (e.g. tailored environments or multi-disciplinary support) as well as hardware issues because the ultimate goal is to provide the researcher at Ames with improved computational resources. Current computational resources include CRAYC90's and IBM SP2, SGI Origin 2000 as well as a network with powerful workstations and super-mini computers.

**Catherine Schulbach**
(650) 604-3180
cschulbach@mail.arc.nasa.gov

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**Large Scale Computing —** Study of high end computing, environments, applications and their implementations as they apply to NASA missions. Studies include large scale systems, architectures, performance analysis, parallelization, and operating systems design.

**Robert B. Ciotti**
(650) 604-4408
ciotti@nas.nasa.gov

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**Information Power Grid —** This research is directed toward a Wide-Area, Heterogeneous High Performance Computing, Communications and. Data environment for Aerospace Applications. Includes architecting seamless grids of high end resources, scheduling, programming services, problem solving environments, metadirectories, multiauthority security for a scalable infrastructure of services.

**Dr. Alex Woo**
(650) 604-6010

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**Rotorcraft Controls and Displays —** Design and evaluation of human-centered cockpit technologies for rotorcraft, flight control theory, control system design procedures and design tools, cockpit display and symbology design principles, guidance and navigation, vehicle and human performance modeling, simulation and flight investigations and demonstrations.

**Jeffery Schroeder**
(650) 604-4037
jschroeder@mail.arc.nasa.gov

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**Rotorcraft Aeromechanics —** Experimental and theoretical research programs to improve performance, vibration, and noise of advanced rotorcraft. Studies include basic investigations of the aerodynamics, dynamics, and acoustics of rotor systems for helicopters, tilt rotors, and other advanced configurations. Experiments are performed in the Ames 7 x 10-foot wind tunnel and in the National Full-Scale Aerodynamics Complex, including the 40 x 80-foot wind tunnel.

**William Warmbrodt**
(650) 604-5642
wwarmbrodt@mail.arc.nasa.gov

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**Experimental Aerodynamics** — Low-speed testing in the 12x24-, 24x37-, and 2x3-meter wind tunnels. Development of computational/empirical prediction methods for powered lift and conventional lift configurations. Prediction and analysis of acoustic characteristics of aircraft configurations and wind tunnel facilities, and the development and application of non-intrusive measurement techniques.

**James C. Ross**
(650) 604-6722
jcross@mail.arc.nasa.gov

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**Computational Fluid Dynamics** — Theoretical research in fluid dynamics using the Euler and the Navier-Stokes equations, both compressible and incompressible. Includes research on basis equation formulations, algorithm development, and code efficiency, as well as the physics of laminar and turbulent flow fields.

**Thomas H. Pulliam**
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pulliam@nas.nasa.gov

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**Turbulence Physics** — Study of the fundamental physics of turbulent and transitional flows through numerical simulations and experiments. Studies include developing numerical algorithms suitable for direct and large-eddy simulations of turbulent flows, developing tools for analyzing computer-generated, databases, developing turbulence models for engineering applications, and performing experiments to understand flow physics and support turbulence model validation.

**Dochan Kwak**
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**Experimental Fluid Mechanics** — Experimental studies of fluid flows of practical interest. Experiments are performed in both the large-scale wind tunnel facilities at Ames and some smaller (specialized) stand-alone wind tunnels. Research areas under investigation include aerodynamics and fluid mechanics, acoustics and aeroacoustics and the development of advanced instrumentation.

**Rabi Mehta**
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**Applied Computational Fluid Dynamics —** This area deals with the development of new computational methodology involving aerodynamic and/or fluid dynamic application associated with incompressible, subsonic, transonic, speeds. Computer codes are constructed and evaluated for applications associated with aircraft or aircraft component aerodynamics, rotorcraft aerodynamics, high-angle-of-attack flow, unsteady flows, and flows with aeroelastic effects.

**Dochan Kwak**
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## SPACE TECHNOLOGY

The work of Space Technology includes both research and development of devices and systems that will be needed on future space missions. Research areas range from the application of computer capabilities simulating the physical and chemical environment, to the direct collection of physical and chemical data. Areas of technology development range from thermal protection during atmosphere entry to methods of rapid and complete organic waste oxidation.

**Carol Carroll**
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**Aerothermodynamics —** Provides aerothermodynamic flow-field computational capability to analyze and design advanced space transportation concepts. Also provides the analytical and turbulence chemistry models required to compute the viscous/finite-rate flow field and to predict radiation heating to conceptual aero-assisted orbital vehicles.

**Paul Wercinski**
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**Aerothermal Materials and Structures —** Develops lightweight reusable ceramics and carbon-carbon Thermal Protection Systems (TPS) for transient, high-velocity atmospheric penetration and develops expendable TPS for planetary probes.

**Daniel Rasky**
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drasky@mail.arc.nasa.gov

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**Computational Chemistry —** Application of molecular structure, molecular dynamics and molecular modeling techniques to a wide range of problems of NASA interest. Current research activities are focused on nanotechnology, device modeling high-energy density materials, combustion research, polymers, astrophysics, aerothermodynamics, and atmospheric chemistry. Specifically, we are interested in computing accurate thermodynamic properties, vibrational frequencies and intensities, molecular line strengths, reaction rates, electron-molecule cross sections, transport properties and spectroscopic constants. We are also interested in porting and extending code for current and next generation parallel architectures.

**Winifred Huo**
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whuo@mail.arc.nasa.gov

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**Applied Computational Fluid Dynamics —** This area deals with the development of new computational methodology involving aerodynamic and/or fluid dynamic application associated with incompressible, subsonic, transonic, supersonic speeds. Computer codes are constructed and evaluated for applications associated with aerospace vehicle or vehicle component aerothermodynamics, high-angle-of-attack flows, unsteady flows, and flows with aeroelastic effects.

**Dochan Kwak**
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**Aerothermodynamics/Hypersonics/IDS tools for TPS —** Provides aerothermodynamic flow-field computational capability to analyze and design advanced space transportation concepts. Also provides the analytical and turbulence models required to compute the viscous/finite-rate flow field and to predict radiation heating to conceptual aero-assisted orbital vehicles. This area deals with the development of new computational methodology involving aerodynamic and/or fluid dynamic applications associated with hypersonic flight speeds relevant for TPS design and sizing. The physical aspects of this flight regime require emphasis on algorithms/codes with accurate heat transfer prediction capabilities, strong shock capturing abilities and chemical equilibrium and non-equilibrium models for air and other planetary atmospheres. For Integrated Design Systems (IDS) for planetary probes/aerobrakes and access to space vehicles, the area creates and modifies complex computer codes that run on mini- and super-computers to model the complex, inter-related physical mechanisms involved in heat shield aerothermal heating and resultant thermal response, and extracts relevant information from experimental data for model validation tools.

**Paul Wercinski**
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## INFORMATION SCIENCES AND TECHNOLOGY

As the Center of Excellence for Information Technology (COE-IT), Ames' primary mission is to provide strategic research focus and Agency-level coordination of NASA's investment in advanced information technology. Ames' role is to pioneer and lead the research, development, and implementation of information technologies to support NASA's Aerospace Enterprise and missions. In support of the four NASA Strategic Enterprises - Aerospace, Space Science, Human Exploration and Development of Space, and Mission to Planet Earth - five information technology focus areas have been identified: Integrated Design Systems; Large-scale Information Management and Simulation; Aviation Operations; Space Systems Operations; and Autonomous Systems for Space Flight.

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**Neuroengineering —** Basic and applied research is conducted in intelligent computational systems technology for Aerospace Missions. Activities address soft computing technologies for real-time performance and adaptability in dynamically changing environments. Current research programs include real-time reconfiguration control for damaged air and spacecraft, early design augmentation and performance estimation using neural, fuzzy, and genetic algorithms, virtual reality simulation of early design prototypes, real-time signal and pattern recognition for fault diagnosis, and evaluation of neural and fuzzy set processing architectures. Emphasis is placed on new methods for rapid gradient search and system identification, integration of soft computing technology with graphic simulation, and new analysis tools to verify adaptive algorithm performance, robustness, convergence, and certification.

**Chuck Jorgensen**
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cjorgensen@mail.arc.nasa.gov

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**Artificial Intelligence —** Basic and applied research is conducted in the framework of aerospace domains including space transportation, space science, and aerospace. Three research areas are emphasized: Planning (including both goal- and resource-driven approaches); machine learning (entire spectrum from empirical to knowledge-intensive); and the design of and reasoning about large-scale physical systems (including work in knowledge acquisition, knowledge base maintenance, and all applications to the design process).

**Mark Shirley**
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shirley@ptolemy.arc.nasa.gov

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**Applied Information Technology —** As an expert center for computer security and workgroup/workflow, Ames will play a considerable role in developing and integrating the "Office of the Future" into the NASA environment. Taking advanced technologies from Ames' Information Technology Center of Excellence and from industry, engineers and computer scientists will adapt these concepts to desktops throughout the Agency

**Scott Santiago**
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## HUMAN FACTORS

Crew performance, aviation safety, aircraft operating systems advanced spatial displays and instruments, virtual environments, high-fidelity simulation-based human performance assessment, operator interfaces to intelligent systems and advanced automation.

**Roger Remington**
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rremington@mail.arc.nasa.gov

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**Virtual Environments —** Research is conducted on the physiological and psychological phenomena that constrain human performance in virtual environment and augmented environments (see -through head mounted displays). Emphasis is placed on operator interaction with virtual objects and improving the perceptual and motor fidelity through geometric, dynamic and symbolic enhancement of the computer graphics, which are used to produce the virtual environments and virtual objects (http://duchamp.arc.nasa.gov/adsp.html).

**Stephen Ellis**
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sellis@mail.arc.nasa.gov

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**Spatial Auditory Displays —** The NASA Ames Spatial Auditory Displays Laboratory conducts basic and applied research in spatial auditory perception and localization with the goal of successfully implementing virtual acoustic displays for improved operator efficiency and safety in aerospace applications. The Lab's work is also concerned with the

human factors of auditory displays in general, including speech communications systems, non-speech warnings and information displays
(http://duchamp.arc.nasa.gov/adsp.html)

**Elizabeth Wenzel**
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bwenzel@mail.arc.nasa.gov

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**Human Perception and Performance —** Current research interests include psychophysiology of human perception and performance, biomedical signal processing, optimization of human performance, and intelligent human-system interfaces (http://vision.arc.nasa.gov/~ltrejo).

**Leonard Trejo**
(650) 604-2187
ltrejo@mail.arc.nasa.gov

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**Visual Displays for Aerospace —** NASA Ames Research Center is investigating displays for cockpit situational awareness, with the intention of assisting the implementation of free flight. This work is in to the RTCA Task Force 3 Report on Free Flight Implementation, which identified cockpit situational awareness displays as a key component of the next generation air traffic management (ATM) system. This report states that "The architecture and technology on which the emerging ATM system is based makes increasingly heavy use of new displays that provide flight crews with real time situational awareness." Therefore, the RTCA report recommends the immediate initiation of "the development of standards for a cockpit situational awareness display of traffic information (CDTI)." Determining these standards requires a detailed human factors evaluation, where the nature and format of the displayed information are examined. The Cockpit Situational Display Research Team has been assigned to assess this task (http://www-cdti.arc.nasa.gov/).

**Walter Johnson**
(650) 604-3667
wjohnson@mail.arc.nasa.gov

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**Vision Science —** Experimental and theoretical research on human vision, and applications of this research to coding, analysis, and display of visual information
(http://vision.arc.nasa.gov).

**Andrew Watson**
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**Image Processing —** Basic and applied research on computational algorithms for automatically extracting information from still images and video data. Current projects in the computational vision laboratory at Ames Research Center include automatic detection of air traffic using airborne cameras, locating features in close-up images of the human eye for movement tracking, and computational assessment of the visual quality of coded or compressed images. These and other applications employ fundamental image processing techniques such as spatial and temporal filtering, registration, and warping (http://vision.arc.nasa.gov).

**Jeffrey Mulligan**
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## ASTROBIOLOGY AND SPACE RESEARCH

The Astrobiology and Space Research Directorate at Ames manages activities in research and technology development in support of NASA's space programs. Work is done in Space Sciences, Life Sciences, and Earth Sciences; in addition, programs are conducted in Space Flight Projects.

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## SPACE SCIENCES

In space sciences, Ames concentrates on research directed at enhancing understanding of the origins, evolution, and current state of the universe. Principal efforts focus on a multidisciplinary approach to research activities, the development and application of selected flight projects, and areas of technology development relevant to those research needs.

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**Infrared Astronomy Projects and Technology Development —** Current research is focused on the integration of the design tools to allow full system simulation prior to SOFIA operation. The technology tasks include IR detectors and cryogenics. Multi-element IR detector arrays are developed and characterized for space astronomy. Advanced efficiency cooling techniques are developed for space.

**Chris Wiltsee**
(650) 604-5917
cwiltsee@mail.arc.nasa.gov

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**Infrared Observational Astronomy and Instrumentation —** Young stars, circumstellar disks, and the interstellar medium are being studied with observations conducted from ground- and space-based observatories. These data are interpreted in collaboration with Ames theorists and laboratory astrochemists. Advanced infrared instruments are also being studied and developed for use on SOFIA, the Next Generation Space Telescope, and other NASA observatories.

Tom Greene
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**Theoretical Astrophysics** — Research is being conducted on star formation, circumstellar disks, the physics and chemistry of the interstellar medium, and the formation and dynamical evolution of galaxies. Theoretical models involve the application of computational techniques to problems in astrophysical gas dynamics, radiative transfer, and many-body systems.

**Pat Cassen**
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David Hollenbach
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**Planetary Science** — Research in this area includes atmospheric, chemical, radiative, and dynamic models, remote sensing of planetary ring dynamics.

**Pat Cassen**
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**Jeff Cuzzi**
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**Exobiology** — Interdisciplinary research in planetary biology is aimed at understanding the factors in cosmic, solar system, and planetary development that have influenced the origin, distribution, and evolution of life in the universe and the course of interaction between biota and earth's surface environments.

**David Des Marais**
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**Planet Formation and Detection of Extrasolar Planets** — Several aspects of planetary growth are being modeled: Agglomeration of dust into planetesimals; dynamical iterations of planetesimals and their accretion into terrestrial planets and giant planet cores; accumulation of giant planet atmospheres. Planets around other stars are being searched for using the photometric (transit) and Doppler (radial velocity) techniques.

**Jack Lissauer**
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lissauer@ringside.arc.nasa.gov

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**Astronomical Data Analysis —** Development of new analysis methods for time series and other data streams from NASA's Great Observatories, including high-energy missions such as gamma-ray and x-ray telescopes. The new algorithms under study include wavelet methods, time frequency distributions, Bayesian statistics and related methods (including implementation of Markov Chain Monte Carlo integrations). In addition, simulations of the dynamical systems thought to underlie the astronomical objects and their luminosity variability are highly informative.

**Jeff Scargle**
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## LIFE SCIENCES

In life sciences, Ames concentrates on biomedicine (the effects of the space environment on man and other organisms); and biosystems (the ability to support man in the space environment).

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**Space Biology —** Space biology research uses the space environment, particularly weightlessness, and ground-based space flight simulations to investigate basic scientific questions about the role of gravity in present-day terrestrial biology. The research is divided into the disciplinary areas of biological adaptation, gravity sensing, and developmental biology. Experiments are carried out at the subcellular, cellular, tissue, organ, and system levels in differing organisms.

**Ruth Globus**
(650) 604-5247
rglobus@mail.arc.nasa.gov

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**Neurosciences —** Research in neuro-sciences examines how the nervous system adapts to environmental conditions encountered in space, how adaptive processes can be facilitated, and how human productivity and reliability can be enhanced. To elucidate mechanisms underlying adaptation, neurosciences research includes neurochemistry, neuroanatomy, neurophysiology, vestibular physiology, psychophysiology, and experimental and physiological psychology. State-of-the-art facilities include: human and animal centrifuges, linear motion devices, an animal care facility, a human bed-rest facility, and NASA's Vestibular Research Facility.

**Mal Cohen**
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mmcohen@mail.arc.nasa.gov

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**Space Physiology —** Multidisciplinary research in space physiology emphasizes the effects of hypergravity, gravity and microgravity on cardiovascular, musculoskeletal, and regulatory systems of humans and animals. Actual microgravity and ground-based models of simulated micro gravity are used to investigate basic mechanisms of adaptation to space and readaptation to Earth. Physiological, biomechanical, cellular, and biochemical factors are also studied to develop appropriate countermeasures for maintaining health, well-being, and performance of humans in space.

**Charles Wade**
(650) 604-3943
cwade@mail.arc.nasa.gov

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**Life Support —** Research is conducted in the broad area of regenerative life support for space: the conservation and re-use of materials consumed by space crews. Issues of interest include the use of physical and chemical devices for air regeneration, water purification, waste management and oxidation and atmosphere contaminant control. Also of interest are systems control, systems modeling and simulation, and the potential role of biological systems in life support supplementation. Mechanical systems of interest include some aspects of spacesuit design.

**Mark Kliss**
(650) 604-3203
mkliss@mail.arc.nasa.gov

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## EARTH SCIENCE

In Earth Science, the focus at Ames is to perform and lead research within the disciplines of atmospheric and ecosystem science, with particular emphasis on how the biosphere and atmosphere interact to influence the evolution of the global system on all time scales.

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**Atmospheric Physics —** Research in this area advances the scientific knowledge and understanding of the physical processes that determine the behavior of the atmosphere on Earth and other solar system bodies. Experimental and theoretical research are conducted in the areas of aerosol and cloud microphysics, atmospheric modeling, atmospheric radiation, and high resolution infrared spectroscopy with the main focus on current environment and climatic issues. By utilizing cutting-edge and information technologies and unique instrumentation**,** research techniques are developed to implement these research goals.

**Warren Gore**
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wgore@mail.arc.nasa.gov

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**Ecosystem Science and Technology —** Interdisciplinary research in ecosystem science and technology looks at the role of life in modulating the complex cycling of materials and energy throughout the biosphere. Intact ecosystems, with particular emphasis on temperate and tropical forests, are examined by remote sensing from aircraft and spacecraft and by field site visits, with subsequent laboratory and computer analysis of the data gathered.

**David Peterson**
(650) 604-5899
dpeterson@mail.arc.nasa.gov

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**Earth Atmospheric Chemistry and Dynamics —** Research in this area includes the development of models and the use of airborne platforms and spacecraft to study chemical and transport processes that determine atmospheric composition, dynamics, and climate. These processes include the effects of natural and man-made perturbations.

**Steve Hipskind**
(650) 604-5076
shipskind@mail.arc.nasa.gov

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**Ecosystem Science —** Research in this area is directed to advanced understanding of the physical and chemical processes of biogeochemical cycling and ecosystem dynamics of terrestrial and aquatic ecosystems through the utilization of aerospace technology.

**David Peterson**
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# Dryden Flight Research Center

## MISSION

- Conduct safe and timely flight research and aircraft operations for current and future aerospace vehicles.
- Conduct atmospheric flight operations for NASA science platform aircraft.
- Support development and operations for Shuttle and future access-to-space vehicles.
- Enhance competitiveness to US aerospace industry.

The Dryden Flight Research Center program includes most engineering disciplines in aeronautics with emphasis on flight systems integration and flight dynamics. The following descriptions identify the current activities relevant to the Dryden program for which qualified students may apply.

### PROGRAM ADMINISTRATOR

Dr. Kajal K. Gupta
Dryden Flight Research Center
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Edwards, CA 93523
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**Advanced Digital Flight Control** — Modeling, simulation, and flight test of distributed control systems. Design criteria and methods for unconventional vehicles, including decoupling of asymmetrical airplanes and stabilization of highly unstable airframes.

**Robert Clarke**
(805) 258-3799

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**Flight Systems** — Engineering aspects of the formulation, design, development, fabrication, evaluation, and calibration of flight control, avionic, and instrumentation systems used onboard complex, highly integrated flight research vehicles. Work with fault tolerant redundant microprocessor-based control systems, microprocessor-based measurement systems, transducers, actuators, techniques for system safety, and hazard analysis.

**Victoria Regenie**
(805) 258-3430

**Flight Dynamics** — Pilot/aircraft interaction with advanced control systems and displays, assessing and predicting aircraft controllability, developing flying qualities criteria, parameter estimation, and mathematical model structure determination.

**Robert Clarke**
(805) 258-3799

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**Flight Test Measurement and Instrumentation** — Flow measurement, skin friction drag, fuel flow, integrated vehicle motion measurements, space positioning, airframe deflection, sensor and transducer miniaturization, and digital data processing.

**Rodney Bogue**
(805) 258-3193

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**Fluid Mechanics and Physics** — Laminar and turbulent drag reduction configuration aerodynamics, experimental methods, wing/body aerodynamics, full-scale Reynolds number test technology, high angle of attack aerodynamics, applied mathematics, and atmospheric processes.

**Robert Meyers**
(805) 258-3707

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**Propulsion/Performance** — Propulsion controls, integrated propulsion/airframe systems, and vehicle performance measurement.

**Ronald Ray**
(805) 258-3687

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**Structural Dynamics** — Aerostructural modeling, vibration and flutter analyses/predictions, aircraft flutter, flight envelope expansion, ground vibration and inertia testing, aeroservo/elasticity, active control of structural resonances, and advanced flight test technique development.

**Mike Kehoe**
(805) 258-3708

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**Aircraft Automation** — Knowledge-based systems development, verification and validation of knowledge-based systems, neural networks, heuristic controllers, knowledge-based acquisition/ implementation, maneuver controllers, performance optimization, guidance, pilot-vehicle interface, and robotic aircraft.

**Lee Duke**
(805) 258-3802

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**Integrated Test Systems and Aircraft Simulation —** Development of Integrated System Test equipment, including aircraft/simulation interface equipment, automated test equipment, and applied artificial intelligence techniques for diagnosis and control. Flight simulation development for advanced aircraft systems in aerodynamic, propulsion, and flight control modeling.

**Vince Chacon**
(805) 258-3791

# John H. Glenn Research Center at Lewis Field

## MISSION

To work as a team to develop and transfer critical technologies to aerospace and non-aerospace industries, universities, and government institutions. NASA has designated Glenn Research Center as its Lead Center for Aeropropulsion. Our role is to develop, verify, and transfer aeropropulsion technologies to U.S. industry. As NASA's designated Center of Excellence in Turbomachinery, our role is to develop new and innovative turbomachinery technology to improve the reliability and performance, efficiency and affordability, capacity and environmental compatibility of future aerospace vehicles. NASA Glenn other Aeronautics and Space Roles and Missions include: Manage a broad array of aeronautics research and technology propulsion activities including propulsion support technology and propulsion systems analysis; space applications involving power and on board propulsion, commercial communications and launch vehicles, and microgravity research in the science disciplines of combustion science, fluids physics, and ground based research.

The Glenn Research Center has a broad research program embracing aeronautical propulsion, space propulsion and power, space electronics, and microgravity science. Brief descriptions of some of the major research activities at Glenn are as follows.

## PROGRAM ADMINISTRATOR

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## PROPULSION SYSTEMS ANALYSIS OFFICE

**Propulsion Systems Analysis —** Advanced propulsion system concepts are conceived and analyzed to estimate performance for typical and advanced, futuristic flight vehicle applications, determine relative merits compared with present and future proposed alternative propulsion systems, and derive optimum designs of systems integrated with a vehicle. Also, analytical and numerical models that predict performance, noise, weight and cost of complete propulsion systems and components are developed, along with models of flight vehicles.

**Barbara Wiedenmannott**
(216) 433-8707

## COMPUTING AND INTERDISCIPLINARY SYSTEMS OFFICE

**High Performance Computing and Communication/Computational Aeroscience —** The cost of implementing new technology in aeropropulsion systems is becoming prohibitively expensive. One of the main contributors to the high cost is the need to perform many large-scale hardware tests. The Computing and Interdisciplinary System Office is developing the technologies required to enable simulations of full aeropropulsion systems in sufficient detail to resolve critical design issues early in the design process before hardware is built. The Numerical Propulsion System Simulation (NPSS) project is focused on the integration of multiple disciplines such as aerodynamics, structures and heat transfer with computing and communication technologies to capture complex physical processes in a timely and cost-effective manner. The vision for NPSS is to be a “numerical test cell” that enables full engine simulation overnight on cost-effective computing platforms. There are several key elements within NPSS that are required to achieve this capability: 1) clear data interfaces through the development and/or use of data exchange standards, 2) modular and flexible program construction through the use of object-oriented programming, 3) integrated multi-level of complexity analysis techniques that capture the appropriate physics at the appropriate fidelity for the engine systems, 4) multidisciplinary coupling techniques and finally 5) high performance parallel and distributed computing.

**Isaac López**
(216) 433-5893

## INSTRUMENTATION AND CONTROLS TECHNOLOGY

**Advanced Sensors, Electronics and MEMS Technology —** Research and development in advanced smart sensing concepts, sensor technology, high temperature electronics materials and devices, MEMS fabrication, integration and applications. Emphasis is on developing advanced capabilities for measurement and control of harsh aerospace propulsion systems. Specific areas of work include extreme high temperature sensors for surface temperature, strain and micro-crack measurements, pressure sensors, remote temperature sensors, heat flux gages, chemical species sensors, silicon carbide crystal growth, modeling, and all areas of electronic device fabrication technology, MEMS micromachining, microfabrication, microsystem integration, testing and harsh environment application. (http://www.grc.nasa.gov/WWW/sensors/SENSORS.HTM)

**Jih-Fen Lei**
(216) 433-3922

**Optical Measurement Systems —** Optical instrumentation technology for aerospace propulsion R&D requirements, for propulsion system control and for space experiments. This technology includes optical sensors and instrumentation for non-intrusive gas path diagnostics and surface measurements. New systems for both point and whole-field measurements of parameters such as velocity, temperature, and species concentration are conceived and developed in the division's laboratories and applied in Center research facilities. (http://www.grc.nasa.gov/WWW/OptInstr)

**Carolyn R. Mercer**
(216) 433-3411

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**Controls and Dynamics Technology —** Development and demonstration of technologies for advanced control concepts and dynamic modeling that enhance performance, safety, environmental compatibility, reliability and durability of aerospace propulsion systems. The controls technology areas include fault diagnostics, health management, active combustion control, active stall control, turbomachinery system stability management, intelligent engine control, integrated flight/propulsion control, nonlinear and robust multivariable control synthesis techniques, and life extending control. The dynamic modeling work includes modeling of advanced turbomachinery concepts and components, and cross-disciplinary research between controls and computational fluid dynamics. (http://www.grc.nasa.gov/WWW/cdtb)

**Sanjay Garg**
(216) 433-2685

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## MATERIALS

**Ceramic-Matrix Composites —** Development of structure/processing/property relationships of ceramic-matrix composites including fibers and fiber coatings for high-temperature, high-reliability requirements for advanced aerospace propulsion and power applications (e.g.SiC/SiC, C/SiC, and oxide/oxide). Various processing approaches, including polymer pyrolysis, melt infiltration, and sol-gel processing, are being pursued. Properties of interest include interface stability flaw distribution, phase morphology, strength, toughness, crack initiation and propagation characteristics, and resistance to environmental attack. In addition, novel approaches for ceramic toughening such as interpenetrating networks are being pursued by conventional ceramic processing and crystal growth. Applications include zirconia fuel cells and high temperature piezoelectrics.

**Stanley R. Levine**
(216) 433-3276

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**Environmental Durability of Advanced Materials** — Research studies to investigate the mechanisms of degradation and to establish and predict the thermochemical stability limits for advanced materials in the high temperature, hostile environments encountered in advanced aerospace propulsion systems. Oxidation, corrosion, and material compatibility of metals, ceramics, polymers and composite materials are studied in air, inert and simulated environments, and under isothermal and cyclic conditions. Various testing and characterization approaches are used to evaluate performance and guide the development of the materials and protective coatings (such as thermal barrier, diffusion barrier, interface control) to improve durability, thus extending the useful life and/or temperature capabilities of advanced materials. Plasma spray, chemical vapor, and physical vapor deposition techniques are used to develop and deposit coatings.

**Leslie A. Greenbauer-Seng**
(216) 433-6781

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**Metallic Materials** — Development of structural metallic materials for aerospace propulsion systems. Intermetallic compounds, superalloys, copper alloys, and composites are being studied for improved performance, higher temperatures, greater durability, and lower cost. Microstructure/property relationships are being developed and experimentally verified. Advanced analytical and microscopy techniques are employed.

**Michael V. Nathal**
(216) 433-9516

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**Polymers and Polymer Matrix Composites** — Development of advanced polymers and polymer matrix composites for use in aerospace propulsion and power and space transportation systems. Areas of research include polymer synthesis, characterization, and processing (including thermal and radiation curing); composite processing, characterization and evaluation; interface studies; polymer/composite aging and life prediction; and determination of structure/property relationships. Research is interdisciplinary and involves work in organic and polymer chemistry, physics, chemical engineering, materials science and engineering, and mechanical engineering.

**Michael A. Meador**
(216) 433-9518

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**Tribology and Surface Science** — Research to gain a fundamental understanding of the lubrication, adhesion, and wear phenomena of materials in relative motion that meet increased speed, load, and high temperature demands of advanced aerospace propulsion and power systems. Liquid, solid, and vapor phase lubricants are formulated and characterized. Novel foil air bearing designs and advanced solid lubricant formulations for use with these high temperature air bearings are investigated. Surface and interface chemistries and morphologies as well as tribological behavior are examined in situ using a variety of techniques including Auger electron and x-ray photoelectron spectroscopy, infrared and Raman microspectroscopy, secondary electron and atomic force microscopy and profilometry.

**Christopher Dellacorte**
(216) 433-6056

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## MICROGRAVITY SCIENCE

**Combustion Science, Fluid Physics & Transport Phenomena, and Space-Based Processes —** Basic science investigations devised to utilize microgravity environment of space to gain new insight in the areas of combustion science, fluid physics and transport phenomena, and space-based process research. NASA Lewis Research Center has a world-class and unique suite of ground-based microgravity research facilities that include: a 2.2 second drop tower, a 5 second zero-gravity facility and a reduced-gravity aircraft. These facilities are utilized to conduct microgravity research and to develop space flight experiments for longer duration microgravity experiments conducted on the Space Shuttle and planned for the International Space Station. Well equipped state-of-the-art laboratories are used to develop new diagnostic techniques/instruments especially suited for use in microgravity research on Earth as well as in space. The experiments conducted in space provide new knowledge that is used to improve processes and equipment used on Earth as well as for exploration of space.

**David L. Urban**
(216) 433-2835
Combustion Science

**Bhim S. Singh**
(216) 433-5396
Fluid Physics & Transport Phenomena

**Howard D. Ross**
(216) 433-2562
Space-Based Processes

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## POWER AND ON-BOARD PROPULSION TECHNOLOGY

**Electrochemical Space and Storage —** Development of advanced technology to increase the life and energy density of energy storage systems and fuel cells. Emphasis is on nearer-term nickel-hydrogen, metal-hydride, lithium ion and hydrogen-oxygen primary and regenerative fuel cell systems, with exploratory efforts being given to more advanced high-temperature ionic conductor systems. Pre-prototypes of advanced battery systems are being designed, built and tested.

**Michelle A. Manzo**
(216) 433-5261

**Mark A. Hoberecht**
(216) 433-5362

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**Electromechanical Systems Technology —** Program management and technology for efficient, compact, lightweight, long life power systems from tens of watts to megawatts for small spacecraft and high altitude, long endurance unmanned aircraft. Program management and technology for advanced electromechanical actuators for aircraft control surfaces. System and mission studies for space, terrestrial, automotive and aeronautical power systems are conducted to identify requirements and technology needs in the areas of energy conversion, thermal management, power conditioning and control, materials and environmental effects. Development of technology to explore the unique potential of the Stirling cycle engine and heat pump for both space and terrestrial applications. Principal emphasis is on developing the free-piston Stirling engine for space-power systems and advanced technologies for cryogenic space refrigeration systems. Among the areas of research are oscillatory flow and heat transfer, heat pipes, materials, non-contacting bearings, dynamic balancing, linear alternators and motors, and insulation.

**Roshanak Hakimzadeh**
(216) 433-8738

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**On-Board Propulsion** — Research and development efforts on high performance electric and chemical propulsion system concepts that are candidates for applications ranging from precision positioning of microspacecraft to primary propulsion for planetary exploration. For electric propulsion, electrothermal, electromagnetic, and electrostatic thruster systems are considered with an emphasis on miniaturization for 21st century missions. The low thrust chemical effort focuses on high performance storable bipropellant engines, green monopropellant and bipropellant systems, and miniaturized systems for microspacecraft. Efforts range from basic research to focused development. In addition to thruster system development, heavy emphasis is placed on the identification and resolution of integration issues critical to the user community.

**Michael J. Patterson**
(216) 977-7481

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**Photovoltaic Cells —** Fundamental and applied research to increase the efficiency, reduce the weight, and extend the life of solar cells for space applications. Emphasis is on III-V compound solar cells, high bandgap materials, and thin film materials. Activities include chemical processing and deposition; materials studies; investigations of radiation damage effects; device design, fabrication, and testing; and the development of related component technologies such as cell contact metallurgy and optical concentrators.

**Dennis J. Flood**
(216) 433-2303

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**Power Systems Surfaces and Materials Technology —** Development of new or improved environmentally durable power materials, high emittance radiator surfaces, high reflectance or transmittance solar concentrators, high thermal conductivity materials and high electrical conductivity composites. Power materials and surfaces are developed by means of intercalation techniques, surface modification technology, and development of thin film protective coatings using various deposition techniques. Evaluations of functional performance and durability are conducted for exposure to atomic oxygen, ultraviolet radiation, vacuum thermal cycling, ionizing radiation and effects of interactions with solar flares, as well as lunar and Martian dust.

**Bruce A. Banks**
(216) 433-2308

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**Space Solar Arrays —** Development of new or improved planar and concentrator array technologies, components, and concepts for small spacecraft that are efficient, stowable, lightweight, long-lived, and less costly than present systems. Array design features of interest include optical, electrical, thermal, and mechanical elements. Test, analysis and development activities can also support large spacecraft arrays including structural analysis of deployment mechanisms, testing system operation in simulated space environments, and studies of new array concepts.

**Dennis J. Flood**
(216) 433-2303

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**Space Environmental Interactions —** Research on radiation damage and electrostatic and electromagnetic effects in space systems and instrumentation (induced by interaction with space plasma and field environments) and on the characterization of local plasma and field environments around large space systems. Effects include surface and bulk dielectric charging, plasma sheath development, current collection from plasma, arcing, and the stimulation and propagation of disturbances. Research disciplines: plasma, solid-state, and surface physics, electromagnetism, and space system design fundamentals, and development of computer programs for simulation and modeling of spacecraft environment interactions.

**Dale C. Ferguson**
(216) 433-2298

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**Space Power Management and Distribution Technology** — Research and technology development to control the generation and distribution of electrical energy in aerospace systems, and to define enabling technology for future aerospace power systems. Technologies being pursued include the development of intelligent modular converter technologies using semiconductor power electronic building blocks and advanced digital signal processors to facilitate the development of plug and play power systems. Furthermore, advanced magnetics and capacitor technology are being investigated along with silicon carbide semiconductor to enhance the overall converter power density and operating temperature range. In addition, work is also being done on high voltage space power systems including switchgear and converters to move to higher power space systems. These technologies will provide the foundation for the next generation of power distribution systems and advanced motor drives for future actuation and flywheel systems for aerospace application. Finally, some work is being done in the Integrated Vehicle Health Monitoring (IVHM) to utilize advanced automation techniques to detect and correct faults within the power management and distribution system.

**James F. Soeder**
(216) 433-5328

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**Thermal Management Technologies** — Analytical and experimental efforts to develop the technologies for high performance heat transport components and systems. Concepts include an all silicon multi-chip module with integrated heat exchanger for space-based data processing as well as motor control for terrestrial electric vehicles. Zero gravity experiments are being done to demonstrate the feasibility of direct immersion heat pipes for cooling electronics in space. Low mass graphite/aluminum radiators are being built for commercial as well as government applications. A test facility has been built which can evaluate steady state and transient performance of high temperature, high power heat pipes.

**Richard K. Shaltens**
(216) 433-6138

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**Thermomechanical Systems Technologies** — Development of technologies for lightweight, high efficiency solar and nuclear thermal power systems. Present emphasis is on the advancement of solar concentrator and heat receiver technologies. Specific concentrator emphasis is related to both rigid and inflatable lightweight structures, reflective and refractive secondary concentrators, high reflectance surfaces and protective films. Heat receiver emphasis is on a heat pipe cavity design with thermal storage. A system conceptual design in 1997 will define advanced solar dynamic technologies required for future space applications.

**Richard K. Shaltens**
(216) 433-6138

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## SPACE COMMUNICATIONS TECHNOLOGY

**Applied RF Technology —** Research and advanced development of phased arrays for space communication systems for commercial applications and NASA missions. Emphasis is on development of K/Ka-band arrays/array feeds in which distributed Monolithic Microwave Integrated Circuit (MMIC) devices provide amplitude and phase weighting; but alternate, potentially lower cost space-fed active array approaches are also of interest. Principal thrusts are on MMIC integration technologies, including MMIC packaging; printed circuit radiating elements and distribution media, beam forming/combining networks and fiber optic links in arrays. Alternative to MMIC phase shifters such as thin film on bulk ferroelectric devices are also under consideration. Systems and technologies for multiple beams, including digital beam forming are also of interest. State-of-the-art antenna metrology facilities are available.

**Alan N. Downey**
(216) 433-3508

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**Digital Communications Technology —** Research and development of advanced digital communications technology in the areas of modulation and coding, advanced routing and digital onboard processing components. Emphasis on the development of next generation digital modems and onboard processing systems for space and ground network applications requiring high data rate throughputs. Specific technologies of interest include: bandwidth and power efficient digital modems and codes; turbo codes; multiple access methods; interoperable digital onboard processing; space-based routers; fast packet switching; and intelligent assistance for autonomous spacecraft operations. State-of-the-art high-speed digital communications systems test-bed, channel simulator, and computer-aided design and simulation facilities are available.

**Gene Fujikawa**
(216) 433-3495

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**Satellite Networks and Architectures —** Development and analysis of advanced aeronautic and space communications architectures and protocols for NASA applications. Specific areas of interest are Transmission Control Protocol/Internet Protocol (TCP/IP), mobile-IP, ad hoc networks, quality-of-service technologies and, where appropriate, Asynchronous Transfer Mode. Also involved are computer modeling of telecommunications networks and simulation of satellite/terrestrial networks using programs such as Berkeley's "NS" network simulation package and Mil3's OpNet.

**William D. Ivancic**
(216) 433-3494
wivancic@grc.nasa.gov

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**Solid State Technology** — Research and development of advanced microwave materials, devices and circuits and the technologies required to integrate individual circuit components into microwave subsystems. Research is focused on solid state circuits for transmit and receive modules in the frequency range of 2-110 GHz. Specific technologies under development include planar transmission lines, passive circuit elements, electromagnetic computer modeling, IV-IV and III-V semiconductor materials for active devices, high temperature superconductor microwave circuits, thin film ferroelectric circuits, and multi-layer microwave circuit components and packaging techniques. State-of-the-art experimental and fabrication facilities include thin film deposition and characterization equipment, automatic network analyzers, room temperature and cryogenic probe stations, and a clean room.

**Vernon O. Heinen**
(216) 433-3245

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**Vacuum Electronics** — Research on vacuum electronics to improve the efficiency, operating life, and communications qualities of electron beam devices for use in space communications. Specific technologies of interest are electron emission (including thermionic, field and secondary emission), electron beam formation and control, electromagnetic/electrodynamic computer modeling and design, application of microfabrication to vacuum devices, and microwave power modules. State-of-the-art experimental and computational facilities are available.

**Vernon O. Heinen**
(216) 433-3245

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## STRUCTURES AND ACOUSTICS

**Advanced Composite Mechanics** — Research for development of theories, computational algorithms, and requisite computer codes for the mechanics, analysis, and design of propulsion structures made from high temperature composites. Of interest are polymer matrix, metal matrix, ceramic matrix, and carbon-carbon composites. Research focuses mainly on specialty finite elements for micro-mechanics and laminate theory; improved theories for life and durability prediction under hostile environment and long time exposure effects; probabilistic composite mechanics; and integrated computer programs for component-specific analysis and design, progressive fracture, acoustic fatigue, damping and high-velocity impact. Selective experimental research is conducted in support of theoretical developments.

**Christos C. Chamis**
(216) 433-3252

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**Aeroacoustics —** Analytical and experimental investigations of the aeroacoustics for air breathing propulsion systems for subsonic and supersonic civil transports. Advanced analyses are developed, applied and validated with experimental data. Model scale tests are conducted in anechoic wind tunnels to identify noise sources and explore new noise reduction concepts. Concepts are developed that reduce aircraft engine noise with minimal impact on aerodynamic performance. Current research emphasis is on fan and jet noise reduction.

**Dennis L. Huff**
(216) 433-3913

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**Computational Structures Technology —** Development, integration, and demonstration of technology to enhance the role of computational modeling in the design and development process for propulsion and power system structural components. Both efficiency and credibility of computational modeling are of concern so technologies that streamline the design/analysis process as well as improve the fidelity of computational predictions are of interest. Specific areas of interest include computer-integrated simulation, multidisciplinary computational mechanics, design optimization, and artificial intelligence. Simulation includes object-oriented technology, information models, product schema, distributed computing, virtual reality, and human interfaces. Computational mechanics includes fundamental mechanics principles, discrete solution methods, and parallel computing algorithms. Design optimization includes mathematical programming and optimality algorithms, heuristic methodology, and multidisciplinary design. Artificial intelligence includes expert systems and neural network applications.

**Dale A. Hopkins**
(216) 433-3260

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**Concurrent Engineering Simulation —** Research for developing integrated software packages for the computational simulation of multidisciplinary procedures through which propulsion structural systems are developed, conceived, designed, fabricated, verified, certified, installed, and operated (concurrent engineering). Of interest are simulation models and software packages which consist of: (1) workstations with discipline-specific modules, dedicated expert systems, and local databases; (2) a central executive module with a global database with communication links for concurrent interaction with the multidiscipline workstation; (3) unsupervised-learning neural nets; (4) adaptive methods for condensing and incorporating information as the system evolves; (5) zooming methods; (6) graphic displays; and (7) computer-generated tapes for numerically controlled fabrication machines.

**Christos C. Chamis**
(216) 433-3252

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**Deformation and Damage Mechanics** — Theoretical and experimental studies of deformation and damage mechanics are conducted to develop accurate methods for determining the deformation response and assessing the useful life of structural components operating at elevated temperatures. Typical examples include turbine vanes, blades, and disks; rocket motor combustion chambers, turbines, and nozzle liners; and hot sections of space and terrestrial power systems. Multiaxial, non-proportional, and non-isothermal loading conditions all prevail in such structures. Research focuses on developing (1) constitutive equations, (2) numerical algorithms for analysis and design, and (3) experimental validation of proposed theories and characterization of material response. Materials under investigation include polycrystalline, single crystal, and directionally solidified metals and their alloys; ceramics; and metallic-, intermetallic-, and ceramic-matrix/fiber reinforced composites.

**John R. Ellis**
(216) 433-3340

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**Fatigue Life Prediction** — Both analytical and experimental approaches are used to develop accurate techniques for predicting durability of aerospace components (turbine vanes, blades, disks, rocket nozzle liners, etc.) subjected to complex service loadings. These are subjected to severe cyclic loads in high-temperature environments. Temperatures are high enough to introduce creep, relaxation, metallurgical transformations, and oxidation. The behavior of materials and structures subjected to such environmental factors is studied in the laboratory, and techniques are developed to allow reliable life prediction in advance of service. Materials under investigation include monolithic alloys and ceramics; and newly developed metallic, intermetallic, and ceramic matrix/fiber reinforced composites. Fully equipped, computer controlled test systems allow rationale behavior to be investigated under uniaxial and biaxial stress states. Also, advanced scanning electron microscopes, transmission electron microscopes, and microprobe facilities are available to investigate fatigue mechanisms at the microstructural level.

**John R. Ellis**
(216) 433-3340

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**Power Transmission Technology** — Power train technology is required for rotorcraft drive systems having higher reliability, longer life and ultrasafe operation, higher power-to-weight ratio, lower noise, lower cost, and higher efficiency. Areas under study include health and usage monitoring systems, new gear arrangements and tooth forms, advanced bearing concepts, materials, lubrication, and cooling. New analytical design and optimization tools for stress analysis, vibration, lubrication, and high-speed gears are being developed. Full-scale helicopter transmission test rigs are available for experimental investigations, as are test rigs for fundamental studies of lubrication, endurance, efficiency, noise of spur, helical, bevel, face, and planetary gear sets.

**Robert F. Handschuh**
(2l6) 433-3969

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**Probabilistic Structural Mechanics** — Research for developing probabilistic structural mechanics, solution/computational algorithms, and requisite computer codes to quantify uncertainties associated with the parameters and variables required for structural analysis and design for both serial and parallel composites. Research focuses mainly on developing probabilistic theories and models for coupled thermal-mechanical-chemical-temporal structural behavior of propulsion structures made from high temperature materials and including metal matrix, ceramic matrix, and carbon-carbon composites and implementation in serial and parallel machines.

**Christos C. Chamis**
(216) 433-3252

**Shantaram S. Pai**
(216) 433-3255

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**Structural Dynamics** — Development of advanced programs for analyzing, predicting, and controlling the stability and dynamic response of aerospace propulsion and power systems. This work includes analytical and experimental studies of the aeroelastic response of bladed disk systems, and both active and passive damping and mistuning methods for controlling the vibration and stability of high-speed turbomachinery. Actively controlled rotors with magnetic suspension are being developed to apply to energy storage flywheel and a more electric gas turbine engine. Innovative computational methods for analyzing multi-component dynamic systems such as an engine/airframe system are being applied. Ballistic Impact experiments and structural analyses for engine containment and probabilistic analyses and design optimization methods are also being developed.

**George L. Stefko**
(216) 433-3920

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**Structural Integrity** — Research to assure integrity and reliability of aerospace propulsion and power systems and structural components. Areas of emphasis include interrogational methods for avoiding catastrophic fracture, fault-tolerant design, defect assessment, and residual life prediction. Comprehensive life prediction models are sought that incorporate complex stress states, nonlinear material characteristics, microstructural inhomogeneities, and environmental factors. Structural integrity is verified by nondestructive characterization of microstructure, flaw population, material morphology, and other relevant factors. Nondestructive evaluation is carried out using analytical ultrasonics, computed tomography, laser acousto-ultrasonics, and other advanced interrogational technologies. Modern computer science practices are exploited to the fullest, and emphasis is on advanced structural ceramics and composites. Integrated computer programs for predicting reliability and life of brittle material components are generated.

**John P. Gyekenyesi**
(216) 433-3210

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**Turbine Engine Seal Technology —** Turbine engine seal technology is being developed for next generation aircraft engines having higher power-to-weight ratio, longer life, higher reliability, and higher efficiency. Areas under study include new seal designs, design optimization, high temperature solid film lubrication, performance and durability tests under engine simulated conditions (up to 1500° F). New analytical design tools are being developed for predicting seal flow rates, for modeling complete turbine secondary air flow systems in which seals play an integral role, and modeling seal stiffness and damping characteristics. A state-of-the-art turbine engine seal test rig is being fabricated to test seals under all temperature, speed and pressure conditions envisioned for next generation commercial and military turbine engines.

**Bruce M. Steinetz**
(2l6) 433-3302

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## TURBOMACHINERY AND PROPULSION SYSTEMS

**Aerospace Propulsion Combustion Technology —** Research to better understand the basic physical and chemical processes in selected liquid rocket engine technologies that are synergistic to aeronautic propulsion. Disciplines include high-energy propellant chemistry, ignition, combustion, heat transfer and cooling in thrust chambers, nozzle flow phenomena, performance, and combustion stability. Of particular interest are the fundamentals involved in: combustion; cooling; nontoxic and in-situ propellant combustion component technologies; micro-combustor technologies including diagnostics and flow analysis; gas-gas injector technology including stability, performance, and compatibility; laser, combustion wave, and catalytic ignition; low cost combustion devices design; and nonintrusive diagnostics including quantitative supercritical spray characterization. Work is conducted through detailed analytical and experimental programs to determine feasibility or applicability and to develop and validate models to describe the processes.

**Chi-Ming Lee**
(216) 433-3413

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**Aircraft Icing —** Analytical and experimental research directed at enhancing safety of flight and developing simulation tools to aid in design efforts associated with flight in icing. Technology elements of interest include: novel concepts for aircraft ice protection/detection; computational and experimental methods for simulation of aircraft icing; fundamental experiments to understand and model the physics of ice formations; computational and experimental methods for quantifying changes in aircraft performance with ice buildup on unprotected components; and novel concepts for remote detection of icing conditions.

Interdisciplinary efforts are devoted to developing instruments to characterize icing cloud properties, measure ice accretion on surfaces, and detect changes in aircraft performance in icing conditions. Experimental research is conducted with a specially equipped Twin Otter aircraft and in the Lewis Icing Research Tunnel, the largest refrigerated icing tunnel in the world.

**Thomas H. Bond**
(216) 433-3900

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**Compressor Technology** — Research to advance compressor technology for gas turbine engines for a wide range of civil and military applications. Areas addressed include advanced axial and radial compressors as well as innovative components such as wave rotors. Experiments to verify selected fluid mechanics computations, allow development of models, and advance understanding of flow physics. State-of-the-art experimental facilities, instrumentation, and data acquisition, reduction, and analysis methods and facilities are employed.

**Kenneth L. Suder**
(216) 433-5889

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**Emissions Technology** — Experimental and analytical research to advance the understanding of emissions formation in combustion processes in subsonic and supersonic gas turbine aircraft engines. Emittants concerned include oxides of nitrogen, speciation of hydrocarbons and sulfur oxides, and carbon-based gaseous or liquid particulates. Experimental work includes emission characterization in flame tube and sector combustors using advanced diagnostics. Analytical work includes the development of new analytical models for processes such as turbulence-chemistry interaction or the use of advanced computer codes to predict combustion emissions and compare with experimental results. State-of-the-art experimental facilities, instrumentation, analysis methods and computational facilities are employed.

**Chi-Ming Lee**
(216) 433-3413

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**Engine Systems Technology** — Analytical and experimental research in propulsion systems for subsonic, supersonic, hypersonic, and space applications. Advanced concepts of interest include rocket-based combined cycles as well as pulse detonation engines.

These are developed through systems studies identifying critical component and component integration issues followed by experiments and additional analyses. Research also includes development and application of new techniques, such as advanced numerical methods, grid generation, and turbulence modeling, for analysis of aerospace propulsion systems. Advanced computational technologies, including parallel processing, interactive graphics, database technology and object-oriented techniques, are applied to propulsion system simulation in order to reduce the time and cost of system design. Optimization and inverse design methods are also of interest.

**Richard A. Blech**
(216) 433-3657

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**Inlet Fluid Mechanics —** Experimental and computational efforts devoted to the fluid mechanics of inlets for aerospace propulsion systems for vehicles ranging from subsonic through supersonic and up to hypersonic. Experiments are intended to demonstrate overall inlet performance, investigate specific inlet flowfield phenomena, provide data sets for the validation of computational methods, and increase the understanding of fundamental inlet fluid physics. Computational research involves application of advanced methods to predict inlet aerodynamic performance, development of improved computational models, and development of new methods to improve computational accuracy and convergence rates. State-of-the-art experimental facilities, instrumentation, analysis methods and computational facilities are employed.

**Thomas J. Biesiadny**
(216) 433-3967

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**Low Noise Nozzle Technology —** Analytical and experimental research on exhaust nozzle aerodynamics and acoustics for high-speed commercial transport applications. The goal is to achieve takeoff noise levels competitive with the best subsonic engine technology. Nozzle system research is conducted with advanced computational codes, and experimentally in large dedicated facilities where aerodynamic and far field acoustic performance, and flow details via advanced flow diagnostics can be determined. Fundamental experiments are also performed in smaller facilities to verify selected fluid mechanics computations and to advance understanding of flow physics of advanced mixing and noise suppression processes.

**Rickey L. Shyne**
(216) 433-3595

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**Propellant Systems Technology —** Research to advance the technology of aeropropulsion propellant systems from ground support equipment to flight and into the low gravity environment. Disciplines include fluid dynamics, heat transfer, thermodynamics and high energy propellant chemistry. Of particular interest are the fundamentals applied to storage, supply and transfer of sub critical cryogens during launch and coast orbits and production, handling and ignition of densified propellants. Work involves development and usage of prediction codes to describe the processes and detailed experimental programs to validate the models.

**Joseph D. Gaby**
(216) 977-7542

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**Turbine Research & Technology —** Research involving the development, assessment, and application of computational fluid dynamics tools and models for turbine design and analysis, and the acquisition and analysis of experimental measurements of flow and heat transfer in turbines. The computational emphasis involves the development and validation of advanced computer codes and models, modification of codes and models to extend range and accuracy, application of codes and models to practical problems. Measurements involve both simplified and realistic, complex geometries, and are used both for the validation of advanced numerical flow and heat transfer analysis codes and for the development of new physical models.

**Raymond E. Gaugler**
(216) 433-5882

# Goddard Space Flight Center

## MISSION

The mission of Goddard Space Flight Center is to expand knowledge of the Earth and its environment, the solar system, and the universe through observations from space. To assure that our nation maintains leadership in this endeavor, we are committed to excellence in scientific investigation, in the development and operation of space systems, and in the advancement of essential technologies. As NASA's lead center for the Earth Observing System, the central component of the Earth Science Enterprise, Goddard's six major laboratories include a broad range of Earth science activities (atmospheres, hydrology, biology and geophysics) related to understanding the Earth as a total ecosystem, as well as a full spectrum of space sciences (astronomy, astrophysics, planetary studies, and space physics) keyed primarily to observations from Earth-orbiting platforms. Strong engineering, flight dynamics, mission operations, communications, data, and computing facilities support these science objectives, allowing Goddard to carry out all aspects of a space-borne science mission from initial concept to final data archiving.

Located on a 1,100-acre campus in suburban Maryland just outside of Washington, DC, Goddard is home to over 4,000 civil servants and 8,000 on-site contractors. Scientific collaborations and industrial partnerships make Goddard the hub of a national and international arena spanning all aspects of science from space.

Graduate Student Researchers Program opportunities are available in the Space Sciences Directorate, the Earth Sciences Directorate, the Applied Engineering and Technology Directorate, and the Systems, Technology and Advanced Concepts Directorate. Research opportunities at Goddard's two remote facilities-the Goddard Institute for Space Studies in New York City and the Wallops Flight Facility on Wallops Island, VA - are included in these listings. Qualified applicants are strongly encouraged to explore areas of interests with the contacts listed prior to submitting a proposal.

All proposals should come to the program office in Greenbelt, MD.

## PROGRAM ADMINISTRATOR

Dr. Gerald Soffen
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## SPACE SCIENCES DIRECTORATE

The Space Sciences Directorate plays a leading role in conceiving and developing instruments and missions for the scientific exploration of space through it's three scientific laboratories:

- Laboratory for Astronomy and Solar Physics
- Laboratory for High Energy Astrophysics
- Laboratory for Extraterrestrial Physics

The Directorate's Space Science Data Operations Office designs, develops, and operates data management and archiving systems and provides public access to archived space science data, and conducts related research.

**Laboratory for Astronomy and Solar Physics —** The Laboratory for Astronomy and Solar Physics (LASP) conducts a broad program of research in experimental and theoretical astronomy, solar physics, and cosmology. Astrophysical phenomena in the sun, stars, and galaxies, as well as the medium between them, are studied with emphasis on their structure, origin, and evolution.

Various groups are actively investigating galactic novae, AGN, starbursts and galactic evolution. Two instruments for the Hubble Space Telescope (HST) have been provided by LASP: the Goddard High Resolution Spectrograph (GHRS), and its replacement, the Space Telescope Imaging Spectrograph (STIS). Data are in hand from the GHRS, and the STIS science team is making use of Guaranteed Telescope Observations (GTO) time to explore fundamental problems in high spatial and spectral resolution spectroscopy.

The Solar and Heliospheric Observatory (SOHO) is currently being operated by the laboratory, and there is much experimental and theoretical work on the structure and dynamics of the sun being done. A new version of the Solar Extreme Ultraviolet Rocket Telescope and Spectrograph (SERTS) is now in fabrication, featuring an all new telescope and detector, designed and developed in the LASP. The launch of the High Energy Solar Spectroscopic Explorer is planned for July 4, 2000.

Within the lab is a strong instrument development program based on both rocket and balloon flights devoted to studying the solar corona, a variety of UV sources, and the cosmic IR and microwave backgrounds. In addition, IR imaging and spectroscopic instrumentation is being developed for ground-based observatories, the Stratospheric Observatory for Infrared Astronomy (SOFIA), and the Space Infrared Telescope Facility (SIRTF).

The Center is developing the Microwave Anisotropy Probe (MAP) for launch in 2000 and is actively pursuing the Next Generation Space Telescope (NGST) concept in collaboration with astronomers and engineers across the community. NGST, a large, infrared telescope, passively cooled to low temperatures, is being studied for launch late in the next decade. There will be many opportunities for technical studies of new instrumentation, new telescope designs, and next generation spacecraft operations.

There are several archival research programs in progress based on data from the Infrared Astronomy Satellite (IRAS), Infrared Space Observatory (ISO), Cosmic Background Explorer (COBE), Solar Maximum Mission (SMM), SOHO, International Ultraviolet Explorer (IUE), GHRS, and STIS.

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Laboratory Chief

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**Laboratory for High Energy Astrophysics —** High Energy Astrophysics is the study, by way of X-rays, gamma rays, and energetic particles, of cosmic systems and sites and the physical processes operating therein. Studies of the mechanisms that release energy and accelerate particles, and of the thermal and non-thermal mechanisms that convert the kinetic energy of these particles into observable radiation, are the essential ingredients of high energy astrophysics. High energy observations and theory address some of the most fundamental problems in physics and astrophysics: the search for the character and location of "dark matter", testing general relativity in the strong gravity limit, the origin and evolution of heavy nuclei, and the ultimate fate of the matter. Studies are made of the accretion disks around, and magnetospheres of, massive compact objects such as neutron stars and black holes; abundance distributions of hot astrophysical plasmas such as stellar atmospheres, supernova remnants, galactic cosmic rays and the interstellar medium; intercluster gas; the origin of gamma-ray bursts; the natural acceleration of particles in space; the central engines of Active Galactic Nuclei; and the nature of large-scale extragalactic structures. A broad program of experimental and theoretical research is conducted in all phases of astrophysics associated with high energy particles and the quanta produced in the interactions with their environments. The observables are features such as compositions, time variability, spatial structures, and spectral features of the X-ray and gamma-ray emissions and particle populations. Experiments are designed, built, tested, and flown on balloons, rockets, Earth satellites and deep space probes. The resulting data are analyzed and interpreted by Laboratory scientists and their associates in the larger high-energy astrophysics community. These studies of the physics of solar, stellar, galactic, and metagalactic high-energy processes lead to development of theoretical models of the origins and histories of these particles and quanta, and provide understanding of the objects and environments in which they arise.

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Archival X-ray and Gamma Ray Data Analysis

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Cosmological X-ray Studies

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Stellar X-ray Sources

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High Energy (>20 MeV) Gamma Rays

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Low Energy (<20 MeV) Gamma Rays

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Gamma Ray Bursts

**J. F. Ormes**
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Cosmic Rays

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Theoretical Studies

**Laboratory for Extraterrestrial Physics —** The Laboratory for Extraterrestrial Physics (LEP) performs experimental and theoretical research on the physical properties of and dynamical processes occurring in the interplanetary and interstellar media, magnetospheres and atmospheres of the planets, including Earth.

The Laboratory proposes, develops, fabricates, and integrates experiments on Earth-orbiting, planetary and interplanetary spacecraft, and sounding rockets. A major effort in the LEP is the analysis of data from spacecraft experiments flown on Voyagers 1 and 2, Lunar Prospector, NEAR, ACE, Ulysses, Cassini, IMP-8, Geotail, Wind, Polar, Mars Global Surveyor, and suborbital rocket payloads.

Space physics research focuses on plasmas, magnetic fields, electric fields, and radio waves located in planetary magnetospheres and the interplanetary medium. A program in infrared astronomy includes the study of spectra of the outer planets to deduce atmospheric properties. Studies of planetary atmospheres and the solar spectrum in the infrared are also conducted. An extensive program of research, including spectroscopy and physical chemistry related to astronomical objects, studies of molecules and chemical reactions of astrophysical and aeronomic importance are also conducted in special laboratory facilities. Research related to the chemistry and physics of planetary stratospheres and tropospheres, and solar system matter including meteorites, asteroids, comet, and planets also forms an important component of the LEP research.

A strong theoretical program exists which includes the study of solar wind turbulence, the modeling of the magnetosphere, the non-linear dynamics of the magnetosphere and the development of the next generation of adaptive grid MHD simulation codes.

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Planetary Atmospheres, Infrared Spectroscopy & Molecular Structure

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Planetary Magnetospheres

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Electrodynamics

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**Space Science Data Operations Office** — This organization offers exceptional opportunities for computer scientists seeking to apply advanced data systems concepts to NASA's challenging space data problems. Areas of interest include massive on-line data management, web-based user interfaces, heterogeneous multi-source databases, and data visualization. Research is conducted on advanced data systems for scientific data management using expert systems, database machines, mass storage systems and computer visualization, and on developing interactive scientific data systems integrating data archiving, catalog, retrieval, data and image manipulation, and transmission techniques into distributed systems.

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Advanced Data Systems

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Mass Data Storage and Data Media

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Computer Visualization

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Data Base Management

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**Space Physics Data Facility** — This organization is engaged in a range of science research and information technology development efforts with missions such as Wind, Polar, and Geotail. Science areas of current interest include coordinated studies of magnetospheric structure and dynamics, trapped radiation modeling, low- energy cosmic ray studies and imaging of the Earth's magnetosphere with radio waves. The organization is active in data standards and the definition, implementation and operation of data systems supporting data acquisition and analysis from current and future space physics missions.

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Cosmic Rays

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Magnetospheric Dynamics

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Trapped Radiation

**Astrophysics Data Facility —** This organization designs, develops and operates data systems that support the processing, management, archiving and distribution of NASA mission data. The staff manages data for specific missions in collaboration with the GSFC Space Science Laboratories and supports the astrophysics community's access to multi-mission and multi-wavelength data archive stored at GSFC. Opportunities exist to study a variety of astrophysical and applied information systems problems, using archived space- or ground-based data. Current areas of staff interest are the interstellar medium, clusters of galaxies, star formation and advanced database technology.

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Information Systems

**Dave Leisawitz**
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Astrophysics

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**HPCC/Earth and Space Sciences (ESS) Project —** Goddard is interested in research which will improve the usability and performance of distributed memory supercomputers. Areas of particular interest include parallel computational techniques, management of massive amounts of data, frameworks, architecture independent programming, and virtual environments. This work is in support of ESS Grand Challenge science applications, which include multi-disciplinary modeling of Earth and space phenomena, and analysis of data from remote sensing instruments.

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**Earth Sciences Directorate**

The are six overall goals of the Earth Sciences Directorate (ESD). In each, scientific efforts involve research, development, and application of advanced space technologies: 1) to develop better knowledge of the distribution and characteristics of Earth’s natural resources and how they are changing and 2) to develop a better understanding of processes affecting global change. The specific goals are:

1. To serve as a national resource for discovery in Earth science and related technology development.

2. To be an international Center of Excellence for research in Earth science and technology.

3. To enhance the nation's technological and scientific literacy by sharing the information and knowledge that result from the performance of Earth science research.

4. To accomplish the Center's mission through a vital and effective work force in the ESD.

5. To take actions that advocate and support the maintenance and upgrading of Goddard's core infrastructure, laboratory facilities, and equipment to preserve the Center's preeminence as a national resource and Center of excellence in the Earth sciences.

6. To support and facilitate the organization of Earth sciences efforts, related technology activities, and business processes that achieve greater productivity in the ESD and throughout the Center.

The Directorate is at the forefront in theoretical and experimental research dedicated to improving the understanding of the structure, dynamics, radiative, and chemical properties of the Earth's atmosphere, including the troposphere, the stratosphere, and the mesosphere from the global scale to the mesoscale.

Research is performed concerning the Earth's surface and interior, extending this research to our planetary neighbors. Data are acquired and analyzed on plate tectonics, continental and regional crustal deformation, and local earthquake hazards. Theoretical and experimental research in oceanic, cryospheric, and hydrologic sciences is performed. The research includes studies of the hydrological cycle, physical and biological oceanography, and cryospheric phenomena such as ice sheets, sea ice, and snow cover dynamics.

Planetary atmospheres, paleoclimate, and geologic structure to improve the understanding and prediction of climate changes on Earth are studied. The Directorate performs computation, modeling, and processing of spaceborne and other observational data, applying the results to improved understanding of the Earth, the solar system, and the universe. Major support is provided to the U.S. Global Change Research Program and to NASA's Earth Science Enterprise by developing and maintaining a comprehensive global change data system. The system archives and distributes Earth Science data from many sources, both national and international, and also generates science data products based on signals from space-based, airborne, and ground-based instruments.

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**Global Change Data Analysis Center** — The Global Change Data Center (GCDC) provides Earth science data operations and archive management to key Earth science flight missions. The Center ensures that data within the archive are readily accessible through the Goddard Distributed Active Archive Center (GSFC/DAAC) and operates key advanced data systems to support NASA flight missions. The GCDC interacts closely with the scientific community being served.

The Goddard DAAC Facility is responsible for the acquisition, archiving, and dissemination of scientific data from specific Earth science missions. It develops, implements, and operates the GSFC/DAAC data system; interfaces the GSFC/DAAC with the other NASA DAAC systems in order to provide timely access to archived data and information; provides special services for the Earth science communities; performs scientific analysis; and generates multi-disciplinary data bases. It also oversees management of the archival systems and facilities of the GCDC; maintains the archive and preserves valuable information content against physical deterioration of the storage media; and produces a regular publication promoting and informing the science user community of its archive contents and services.

The Earth Science Data Operations Facility works closely with flight project personnel in data system planning and utilization, and develops and implements the capability to support Earth sciences mission needs. The Facility is responsible for supporting instrument algorithm development and operational project data set production systems; developing such systems for specific NASA flight projects such as the Earth Probes; and developing nationally accessible advanced data projects for the area of Earth science. It conducts research in advanced computer science methodologies for application to science data operations, and oversees management of the computer systems needed to process project data systems.

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Goddard DAAC Facility

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**Laboratory for Atmospheres** — This laboratory performs a comprehensive theoretical and experimental research program dedicated to advancing our knowledge and understanding of the atmospheres of the Earth and other planets. The research program is aimed at advancing our ability to predict the weather and climate of the Earth's atmosphere; advancing our understanding of the structure, dynamics, and radiative and chemical properties of the troposphere, stratosphere, mesosphere, and thermosphere; determining the role of natural and anthropogenic processes on the ozone balance and climate change; and advancing our understanding of the physical properties of the atmospheres and ionospheres of the Earth and other planets.

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**Data Assimilation Office —** Data assimilation combines information from observations with information from prognostic models to produce optimal time series estimates of the Earth. This Office advances the state-of-the-art of data assimilation and the use of data in a wide variety of Earth system problems, develops global data sets that are physically and dynamically consistent, provides operational support for NASA field missions and Space Shuttle science, and provides model-assimilated data sets for the Earth Science enterprise.

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**Mesoscale Atmospheric Processes Branch —** This branch performs research on a broad range of meteorological problems ranging from convective cloud scale through synoptic scale to the global scale. The research emphasis is on the initiation, evolution, and impact of atmospheric precipitating systems and on the remote measurement of precipitation. Scientists in the branch employ theoretical and numerical modeling methods, observational analyses, and participate in sensor development for the measurement of precipitation, clouds, and water vapor. Specific topics include tropical and mid-latitude convective precipitation systems, fronts and gravity waves, tropical and extratropical cyclones, air-surface interactions, and global precipitation analysis. The branch also conceives and develops advanced remote sensing instrumentation to measure meteorological parameters with emphasis on lidar systems.

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**Climate and Radiation Branch —** This branch conducts basic and applied research with the goal of improving the fundamental understanding of regional and global climate on a wide range of spatial and temporal scales. Emphasis is placed on the physical processes involving atmospheric radiation and dynamics, in particular, processes leading to the formation of clouds and precipitation and their effects on the water and energy cycles of the Earth. Currently, the major research thrusts of the Branch are: climate diagnostics, remote sensing applications, hydrologic processes and radiation, aerosol/climate interactions, and modeling seasonal-to-interannual variability of climate.

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**Atmospheric Experiment Branch —** This Branch conducts experimental research in terrestrial, cometary and planetary atmospheres concerning chemical composition, atmospheric structure and dynamics. Scientists and engineers in the Branch participate in scientific investigations from experiment conception through flight hardware development, space flight and data analysis and interpretation. Neutral, ion, and gas chromatograph mass spectrometers are developed to measure atmospheric gases from entry probes and orbiting satellites.

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**Atmospheric Chemistry and Dynamics Branch —** This Branch conducts research aimed at understanding the radiation-chemistry-dynamics interaction in the troposphere-stratosphere-mesosphere system. This Branch develops remote-sensing techniques to measure ozone and other atmospheric trace constituents important for atmospheric chemistry and climate studies, develops models for use in the analysis of observations, incorporates results of analysis to improve the predictive capabilities of models, and provides predictions of the impact of trace gas emissions on the ozone layer.

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**Laboratory for Terrestrial Physics —** The Laboratory for Terrestrial Physics (LTP) advances the scientific knowledge of the Earth and planetary solid-body physics. In the scientific branches, research is pursued on the distribution of mass within the Earth-ocean-atmosphere system, the origin of the Earth's magnetic field, the nature of the movement of the tectonic plates which form the Earth's crust, the effect of variation in the momentum of the atmosphere and changes in the hydrosphere on the Earth's rotation rate, the role of vegetation in the carbon cycle, the most efficient dataset required to detect and interpret change at the ecosystem level, and the nature of the interior structure of the Moon, Mars and Venus. The Laboratory has a significant capability to design, develop and test laser and electro-optic remote sensing instruments. The LTP has designed and managed several spacecraft instruments.

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**Geodynamics —** Research topics include the structure and composition of the Earth's interior through geodetic studies of the gravity and magnetic fields, the study of the lithosphere through magnetic anomalies, the rotational parameters of the Earth and planets, the measurement of Earth and planetary topography with altimeters and the study of planetary landforms and surface processes as related to crustal evolution.

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**Terrestrial Information Systems —** Advances research programs and institutional administrative activities through research in and applications of information technology. Activities include development of data systems to process and distribute information from Earth observing satellites, aircraft sensors, ground-based networks and field experiments, develop software for visualization, analysis, and presentation of scientific data.

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**Biospheric Studies —** Biospheric studies include research on terrestrial ecosystem-atmosphere interactions, and ecological patterns and processes occurring at local, regional and continental spatial scales, as well as basic remote sensing research. A wide variety of remote sensing models and passive and active instruments are used to develop a fundamental understanding of the interaction of electromagnetic radiation with terrestrial surfaces. Laboratory, field, aircraft, and satellite investigations are used to characterize the spectral distribution, bi-directional reflectance, and polarization response of terrain features at visible, infrared and microwave frequencies. Techniques are developed to create, process, and analyze multi-year global datasets. Time series of satellite data are used to study the seasonal dynamics of global vegetation, interannual variations in production of semi-arid grasslands, tropical forest alteration, and to provide improved surface characterization for input into global models.

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**Laser Instruments —** Designs and develops advanced electro-optic and laser sensors for ground-based, airborne and spaceborne Earth and planetary science investigations. Work includes laser and detector research, sensor development research and conceptual design, performance calculations, sensor engineering and fabrication, as well as calibration and integration. Sensors are used for measurements of Earth and planetary surfaces and of the

Earth's atmosphere and oceans. The branch also develops advanced laser sensors, including laser altimeters and lidar systems, for airborne and spaceborne use.

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**Space Geodesy —** Space Geodesy research studies the motion of the Earth on its axis, the kinematics of plate motion and deformation of the crust, the Earth and ocean tides, variations in sea level, core dynamics, and models of the gravity fields of the Earth and planets. Data comes from precise geodetic methods, including laser ranging and very long baseline interferometry, altimetry, data from highly accurate tracking systems such as GPS and doppler, gradiometry and satellite-to-satellite tracking.

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**Laboratory for Hydrospheric Processes —** The Laboratory performs theoretical and experimental research on various components of hydrology and its role in the complete Earth science system. The program is aimed at observing, understanding, and modeling the global oceans and ice, surface water, and mesoscale atmospheric processes. The Laboratory conducts research on Earth observational systems and techniques associated with remote and in-situ sensing.

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**Oceans and Ice Branch —** This Branch conducts oceans and ice research to enhance understanding of these systems and their relationships with other elements of the Earth's climate. Research focuses on problems in biological, physical, and polar oceanography; glaciology; and marginal ice zones, air-sea interactions, and coupled climate modeling. Interdisciplinary studies on problems such as those involving productivity and carbon fluxes, upper ocean and thermohaline circulation of the oceans; ice/ocean coupling; and ice sheet dynamics are conducted.

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**Observational Science Branch (Wallops Island, VA) —** This Branch conducts theoretical and experimental research to validate, calibrate and extend measurements made by Earth Science satellite sensors, as well as explores and develops new technology for improving measurements made not only from satellite but also from aircraft and ground-based instrumentation. It enables science by monitoring satellite altimeters such as TOPEX and quality controlling data they collect. The Branch also conducts fundamental research on Earth Science processes both in the laboratory and in world wide field campaigns. The Branch does so by maintaining and operating research facilities which include: Air-Sea Interaction Facility, Rain-Sea Interaction Facility, Rain Simulation Facility and instrumentation systems which include: Airborne Oceanographic Lidar, Airborne Topographic Mapper, Scanning Radar Altimeter, Radar Ocean Wave Spectrometer, TOGA and New TRMM Research Weather Radars, Dobson spectrophotometer, and balloon-borne ozone and meteorological sensors. The Branch is located at the NASA GSFC Wallops Flight Facility at Wallops Island, VA.

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**Hydrological Sciences Branch —** The Hydrological Sciences Branch conducts research activities that contribute to an improved understanding of the exchange of water between the Earth's surface and its atmosphere. These research activities emphasize the use of remote sensing over a wide range of electromagnetic frequencies as a means of studying various hydrological processes and states, such as precipitation, evapotranspiration, soil moisture, snow and ice cover, and fluxes of moisture and energy. In addition, advanced numerical and analytical models are developed.

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**Microwave Sensors Branch —** This Branch performs research and development on advanced microwave sensing systems and data collection systems directed at providing remote and *in-situ* data for research in the areas of the oceans, ecology, weather, climate, and hydrology. The Branch performs basic theoretical, laboratory and field studies that elucidate the interaction of electromagnetic radiation with the environment to improve our understanding of remote sensing systems. Branch members contribute to the development of microwave science and engineering for the Tropical Rainfall Measurement Mission (TRMM), the Earth Observing System (EOS), and various airborne campaigns.

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**SeaWiFS Project —** The Sea-viewing Wide-Field-of-view Sensor (SeaWiFS), was successfully launched on Orbital Sciences Corporation’s SeaStar satellite on August 1, 1997, and is providing global observations of ocean color for NASA. These data are being used to assess phytoplankton abundance, ocean productivity, and the ocean's role in the global carbon cycle. In addition, the observations are useful for visualizing ocean dynamics and the relationships between ocean physics and large-scale patterns of productivity. The SeaWiFS Project is responsible for the validation of the data products which includes the sensor calibration, atmospheric correction, and bio-optical algorithms.

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**SIMBIOS Project —** The Sensor Intercomparison and Merger for Biological and Interdisciplinary Oceanic Studies (SIMBIOS) Project will develop a methodology and capability to combine data products from various ocean color satellite instruments, e.g. SeaWiFS, OCTS, POLDER, and MODIS, in a manner that ensures the best possible global coverage. This work requires evaluations of the sensor characteristics and calibrations, and the atmospheric correction and bio-optical algorithms used by each flight project. The project is supported by the SIMBIOS Science Team who collect much of the field data used for product evaluation. The developed merged data set will improve the ability to capture short term changes in the ocean more effectively than any individual ocean color mission. The data will then be used to assess phytoplankton abundance and model ocean primary productivity and associated atmospheric-ocean carbon transfer.

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**Earth and Space Data Computing Division —** The Earth and Space Data Computing Division (ESDCD) enables NASA-supported scientists to increase their understanding of Earth and its environment, the Solar System, and the Universe through the computational use of space-borne observations and computer modeling. To help assure the research success of NASA- and Goddard Space Flight Center (GSFC)-related projects and programs, we are committed to providing the science community with access to state-of-the-art high performance computing, leading-edge mass storage technologies, advanced information systems, and the computational science expertise of a staff dedicated to supporting that community.

The ESDCD manages and operates the NASA Center for Computational Sciences (NCCS), a primary supercomputing and data storage center for support of NASA missions and programs, and, on a national basis, for approved programs of the external NASA and university communities. The ESDCD utilizes state-of-the-art computational equipment and data systems to provide end-to-end support of computational research conducted by the Earth and Space Sciences Directorates at GSFC and to a somewhat lesser extent external NASA approved research investigators. Specifically, the ESDCD meets its science-driven requirements by providing specialized computational processing and archival services for approved projects and individual scientists as well. In addition, the ESDCD provides support in the areas of sensor algorithms for direct ground communications readout of satellite transmissions, information processing, discipline data base management systems, high performance computing and parallel processing, high speed local and wide area network support, and advanced science data visualizations systems.

The NCCS engages in the application of advanced computer system architectures, such as a suite of CRAY J932, IBM SP and SGI Origin 2000 computers, and scalable parallel machines such as the SGI/CRAY T3E, to support complex computational physics modeling efforts. These modeling efforts involve, for example, studies of coupled multi-dimensional ocean and atmospheric systems, multi-dimensional magnetospheric-ionospheric systems, and astrophysical processes. Specific research opportunities exist for development of new numerical algorithms in computational physics that utilize advanced computer architectures, development of advanced scientific visualization, algorithms for visualization of space and Earth science processes, and the development of advanced techniques for managing decaterabyte mass data storage and delivery systems.

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## GODDARD INSTITUTE FOR SPACE STUDIES (NEW YORK, NY)

**Goddard Institute for Space Studies (New York, NY) —** The Goddard Institute for Space Studies conducts comprehensive theoretical and experimental research programs in four major areas.

**Planetary Atmospheres —** Concerned with investigations of Jupiter, Saturn, Venus, Mars, and the Earth. The observational phase of the program includes imaging and polarization measurements from the Pioneer Venus Orbiter, radiation-budget, temperature-sounding, photometric, and polarization measurements from the Galileo Jupiter Orbiter, temperature mapping from Mars Climate Orbiter, Cassini imaging of the Jupiter-Saturn system, and Titan wind measurements from the Huygens probe. The theoretical phase of the program includes interpretation of radiation measurements of planets to deduce bulk atmospheric composition and the nature and distribution of clouds and aerosols, and analytical and numerical models of planetary circulations. Emphasis in the theoretical program is on analysis of physical processes in terms of general principles and models applicable to all planets.

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Atmospheric Dynamics

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Radiative Transfer

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**Causes of Long-Term Climate Change —** Causes of Long-Term Climate change encompasses basic research on the nature of climate change and climatic processes, including the development of numerical climate models. Primary emphasis is on decadal to centennial global-scale simulations, including studies of humanity's potential impact on the climate. Climate sensitivity and mechanisms of climatic change are investigated in global paleoclimatic research, specifically from the comparison of pollen and glacial data with paleoclimatic model simulations. In addition to their use for climate simulations, the global models are used to simulate the transport of atmospheric constituents and thus study their global geochemical cycles. The program also includes development of techniques to infer global cloud, aerosol and surface properties from satellite-radiance measurements as part of the International Satellite Cloud Climatology Project and the Earth Observing System and analysis of the role of clouds in climate.

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Greenhouse Effect

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Paleoclimate, Pollen Studies

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Climate Dynamics, Stratosphere

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Global Cloud Properties

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Radiative Processes

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**Remote Sensing of Clouds and Aerosols —** Remote Sensing of Clouds and Aerosols is concerned with the development and application of techniques to infer cloud and aerosol properties from satellite radiance measurements as part of the International Satellite Cloud Climatology Project (ISCCP), the Global Aerosol Climatology Project (GACP) and the Earth Observing System (EOS). This program includes the validation of the retrieval products through the correlative analysis of *in situ*, ground-based, airborne and satellite data; the development and application of algorithms designed to fully exploit the information content of multispectral radiance and polarization data and the analysis of multi-sensor satellite data sets. Essential to this program is the analysis of the role of clouds in climate and the evaluation of aerosol direct and indirect radiative forcings. This program also includes theoretical studies of single and multiple scattering of electromagnetic radiation by cloud and aerosol particles.

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**Interdisciplinary Research —** Interdisciplinary research ranges from theoretical studies of the origin of the solar system to relationships between the Sun, terrestrial climate, geological processes, and biology. One phase of the program involves the structure and evolution of accretion disks, especially the primitive solar nebula, using models of large-scale turbulence. Another area concerns the evolution and pulsation of bright stars, which may be analogs of the Sun. A biological question of special interest concerns how terrestrial vegetation will change during the next 50 years, when climate and atmospheric $CO_2$ are expected to be changing. Related research topics involve impacts of climate variability and change in integrated biophysical and socioeconomical systems.

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Stars, Climate Studies

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Climate Impacts, Agronomy

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**Applied Engineering and Technology Directorate (AETD) —** The AETD has the full range of discipline engineering capability required to support all phases of NASA's current Earth and Space Science missions and implements a broad range of advanced technology initiatives required to enable and enhance a new generation Space and Earth Science missions.

AETD provides discipline engineering expertise in the areas of information systems; electrical systems; mechanical systems; guidance, navigation and control; and scientific instrument development. AETD designs, develops, and tests components, subsystems, scientific instruments, and spacecraft for NASA programs and projects including the Microwave Anisotropy Probe, the Earth Orbiter 1, the Hubble Space Telescope, and many others. The Directorate also provides the engineering and technical discipline expertise required to development spacecraft (such as, the Geostationary Operational Environmental Satellite series) for external customers like the National Oceanographic and Atmospheric Administration.

AETD conducts innovative technology research & development for scientific space applications in a number of focus areas including:

- Large Aperture Systems (synthetic aperture, segment/adaptive optics, large lightweight deployables, thermal control surfaces, etc.)
- Advanced Instruments (optical components, laser sensing, cryogenic coolers, radiation detectors, microwave sensors, etc.)
- Distributed Observatories (micro/nano satellites, formation flying, platform subsystem component technologies, etc.)
- Rapid Formulation/Execution Environment (collaborative & virtual environments; intelligent Systems; advanced simulation tools; etc.)
- End-to-End Science Information Systems (autonomy, software tools, data processing, communications, reconfigurable computing, etc.)

These technologies are developed for future NASA programs and projects including Next Generation Space Telescope, Nanosat Constellation Trailblazer, Earth Observing System, and many others.

In fulfilling Goddard's mission, AETD also provides engineering and technology development support to other NASA Centers, other government agencies, national laboratories, industry, and academia. The Directorate partners with others to accomplish the Nations space objectives in the most effective manner possible while transferring knowledge and technology to enhance the Nation's scientific and technological literacy as well as its economic well being.

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**Thermal Development Branch —** This branch is responsible for the development of new thermal control technology for future NASA spacecraft. Current work efforts focus on such technologies as cryogenic heat pipes, two-phase capillary pumped loops, and heat pumps. The scope of the work encompasses concept development, breadboard to prototype testing, conduction of flight experiments, and analysis. The 7000 square foot laboratory/office area has numerous test loops. These range in size from small benchtop units to an 8 ft. by 30 ft. facility, which is the largest known modular two-phase test bed. A wide variety of instrumentation, data collection/processing, and other support equipment are available to support these testing efforts.

**Theodore Swanson**
(301) 286-8618

**Jentung Ku**
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**Optics Branch —** The Optics Branch conducts research and development programs in the optical sciences and engineering to support flight experiment development in the areas of high energy astrophysics, solar and stellar astronomy, atmospheric sciences, and ocean and terrestrial sciences. Specific research and development objectives include optical property characterization of solids and thin films, diffraction grating technology, optical system design and analysis, and advanced optical fabrication and testing. Modern laboratory facilities are equipped for optical property studies in the far infrared to extreme ultraviolet, generation of holographic diffraction gratings, and optical fabrication and testing. In addition, extensive computer facilities are available to support optical design and analysis studies.

**David Content**
(301) 286-7382

**Ritva Keski-Kuha**
(301) 286-6706

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**Lasers/Electra-Optics Laboratory —** The Lasers and Electro-Optics Laboratory conducts applied research in Electro-optics including high power semiconductor lasers, diode pumped solid state lasers, photo refractive filters, acoustic-optic tunable filters, Fourier transform interferometers and photon counting detectors for remote sensing instruments. A major thrust is the investigation of the use of laser diodes as the transmitter source for active remote sensing instruments. Both the physics and engineering aspects of these systems are under investigation. Instrumentation is being developed and demonstrated for ground-based and flight observational research from ultraviolet to infrared wavelengths.

**William Heaps**
(301) 286-5106

**Michael Krainak**
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**Electromechanical Systems Branch** — The Electromechanical Systems Branch develops mechanical, optomechanical, and electromechanical systems required to support flight instrument and spacecraft projects. Conducts advanced and supporting research and development efforts to support new technology, such as magnetic bearings and cryogenic mechanisms, applicable to existing and future spaceflight requirements. Deployable appendages such as magnetometer booms and 100-meter long electric field antennas are developed. Flight structures ranging in size from small optical benches to instruments weighing several tons are provided. Electromechanical systems and their control electronics are developed, taking into account the effect of spacecraft disturbances where applicable. Modem laboratory facilities are equipped for electromechanical fabrication and testing.

**Mike Hagopian**
(301) 286-7854

**Willie Blanco**
(301) 286-3637

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**Cryogenic Detectors and Technology Development —** The Cryogenics group actively conducts research and development programs in low temperature physics in support of astrophysics goals. General research objectives are the development of low temperature microcalorimeters for the detection and imaging of charged particles and radiation, and high-precision and high-accuracy thermometry. Current research focuses on large format detector arrays using thin-film superconductors for imaging x-ray and infrared sources with high-energy resolution, as well as the SQUID systems used for readout. Modern laboratory facilities are equipped for detector characterization and fabrication, including cryogenic workstations with automated data collection, SQUID systems, dilution and adiabatic demagnetization refrigerators, and facilities for evaporation and sputtering of thin films.

**Stephen Castles**
(301) 286-5405

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**Mechanical Engineering Branch** — The Mechanical Engineering Branch performs structural and mechanical design for in-house STS and ELV launched spacecraft, instruments, and mechanical ground support equipment. These designs include spacecraft and instrument primary and secondary structures; deployable appendages such as solar arrays and antennas and extendible optical benches; inflatable structure technology; flight mechanisms such as actuators, hinges and release mechanisms; and mechanical ground support equipment such as lift slings, dollies, containers, and g-negation hardware. The Branch also provides support for fabrication, assembly, integration, and testing of spacecraft and instrument structures including structural design research and design optimization of advanced composite materials. The Branch provides advanced development for maintaining state-of-the-art concurrent engineering and CAD/CAM technology.

**James Ryan**
(301) 286-6003

**Gary Jones**
(301) 286-5837
Mechanical Systems

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**Microwave Instrument Technology Branch** — This Branch provides engineering and technology expertise to instrument development teams, study teams and proposal teams for end-to-end conceptualization and development of microwave systems. Emphasis is placed on the development of new capabilities that require innovation and present significant challenges in meeting specifications derived from science requirements. Advanced technologies and concepts are demonstrated which enable new measurements, improved performance, and reduced cost, size, and mass of sensors. This Branch also integrates and tests microwave instrument systems, performs system analysis, and supports experimental field campaigns, airborne and space missions.

**Catherine Long**
(301) 286-8493

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**Advanced Architectures and Automation Branch** — This Branch develops and applies systems, hardware, and software technologies to support complex command and control, communications, and telemetry data processing requirements for future space missions. A major focus of its work is in the development of autonomous ground/space systems. The Branch also supports work in the area of advanced intelligent information management. The Branch performs advanced technology development in such areas as: high-performance VLSI systems for telemetry processing, high data rate/volume data storage architectures, distributed systems and networks, computer-aided software and systems engineering, human-machine interface and interaction technologies, artificial intelligence (especially in the areas of expert systems, agents and agent communities, multi-modal reasoning (rule-based, case-based, model-based), neural networks, genetic algorithms, etc.), planning and scheduling (both centralized and distributed), monitoring and control, intelligent trend analysis, data and information visualization, virtual environments, and intelligent information management. The Branch also engages in usability testing and cognitive studies associated with human/system interfaces and interactions. Branch laboratory facilities provide some of the most advanced systems design and development capabilities available, including a complete suite of VLSI design tools, libraries, and workstations; workstations including SUN, HP, and Silicon Graphics; advanced tools for system and software engineering, modeling and human/computer interface design; and expert system shells and development environments.

**Julia Breed**
(301) 286-5049

**Barbara Brown**
(301) 2864438

**Walt Truszkowski**
(301) 286-8821

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**Microwave Systems Branch** — The Microwave Systems Branch is responsible for conception, analysis, design, development and engineering of state-of-the-art RF, microwave, millimeter wave and higher frequency components and systems for GSFC communications and instrument applications. It also provides communications and microwave instrument discipline support to other GSFC organizational elements and flight projects. The Branch maintains core microwave engineering discipline support and facilities and develops and tests state-of-the-art microwave instrument and communications antennas. Efforts are concentrated on analytical design methods, but also includes materials properties, test and calibration methods, manufacturing techniques, and deployment procedures. The Branch, with appropriate spacecraft designers, develops spacecraft communication systems using current and advanced technology; analytical studies and experimental investigations are proposed and conducted technology developments are conducted in support of these major mission responsibilities with emphasis on antennas, low noise receivers, radiometers and related instrument technologies, and transponders. The Branch develops flight and ground communications equipment in support of the tracking and data acquisition requirements of GSFC low earth-orbit, suborbital, and balloon flight projects.

**John Chitwood**
(301) 286-7665

**Ken Perko**
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**Component Technologies and Radiation Effects Branch** — The Component Technologies and Radiation Effects Branch provides unique and essential parts, radiation, and advanced technology support to internal and external customers and partners to meet mission reliability, cost, and schedule goals in the areas of flight project support and applied research. Flight project support encompasses aspects of reliable systems development including: space environment definition and simulation, part selection, evaluation and testing, instrument development and calibration, characterization and validation of technologies, application engineering, anomaly investigation, and maintain databases for parts and radiation information. The applied research aspects of the branch support efforts in: parts and technology issues, emerging and state-of-the-art technology developments, development and extension of device and environment models, emerging radiation hardness assurance issues, instrument and payload development, novel materials and microelectronics developments, emerging photonics, evaluation and analysis of space flight data (including anomalies), partnerships, and technology transfer.

**Darryl Lakins**
(301) 286-6631

**Harry Shaw**
(301) 286-6616

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**Microelectronics and Signal Processing Branch** — The Microelectronics and Signal Processing Branch designs, develops and infuses leading edge microelectronic devices and components for flight and ground customer applications. This includes front-end electronics interface, analog signal filtering and conditioning, analog cryo temperature control systems, analog multiplexing and A/D conversion, digital signal processing and compression, C&DH and downlink interfaces. In addition, the Branch is responsible for analog and digital circuits which support various sensors and actuators. The Branch develops concepts and designs, prototypes and tests these designs, builds engineering and flight models and performs subsystems testing and delivers these systems to the instrument or spacecraft developer. The Branch provides expert personnel and maintains tools capable of developing highly integrated ASIC and VLSI devices and modules for instrument, spacecraft and ground components. The Branch maintains the expertise in advanced and high speed analog and digital device design for both flight and ground applications, VLSI design experts in custom, semi-custom, and programmable devices, device packaging techniques such as multichip modules, chip on board, and state of the art surface mount technology, circuit design methodologies (VHDL, Verilog) and advanced algorithmic development.

**Bob Kasa**
(301) 286-8043

**Tim Sauerwein**
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**Power Systems Branch —** The Power Systems Branch provides technical expertise in the field of electrical power for space applications. Power subsystem engineering is provided to support all phases of scientific instrument, special payload, and spacecraft flight programs from conceptual design, through hardware development and test, to end-of-life operations. The Branch performs applied research and development work to advance current power system technologies. Electrochemical discipline engineering support is provided to advance energy storage technologies by developing longer life, longer life and higher energy density primary and secondary batteries for special payloads and spacecraft applications. Photovoltaic discipline engineering support is provided to advance solar-electric energy conversion technologies by developing higher efficiency solar cell arrays for spaceflight applications. Electronics discipline engineering is provided to advance power management, distribution, and conditioning technologies by developing efficient, low noise, high and low voltage power regulators and converters for scientific instruments, special payloads, and spacecraft.

**Marlon Enciso**
(301) 286-5845

**Tom Yi**
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**Flight Electronics Branch —** The Flight Electronics Branch is responsible for providing the technical expertise in the development of Flight Data Systems and its related components for space flight applications, and in the discipline area of Command and Data Handling systems engineering. This engineering support is provided to Earth/Space Science, other Engineering Centers and the Flight Program and Projects Directorate for both in-house and out-of-house efforts with regards to the analysis, design, fabrication, procurement, test, integration, and operation of Flight Data Systems and related components for instrument and spacecraft payloads. The Branch spearheads the development of advanced technologies in instrument/spacecraft data buses, radiation-hardened microprocessors, mission unique electronics, instrument & spacecraft subsystem interface devices, and bulk storage components. The Branch supports the development of new instrument/spacecraft architectures with regards to partnering with industry and other agencies, proposal development, and phase A&B studies and supports the development of advanced GN&C and mechanism electronics.

**Bob Stone**
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**Phil Luers**
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**Electrical Systems Branch —** The Branch designs and develops orbital, suborbital and carrier electrical systems and selected flight components such as harnesses, flight fiber optic networks, and special purpose interface hardware. It provides electrical systems leads to Instruments and for Project teams who develop electrical interfaces, performance requirements, functional test procedures, and electrical specifications for in-house space programs or provide oversight and electrical systems expertise to out-of-house space programs. The Branch develops mission critical range instrumentation systems by employing new technology insertion to improve the functions necessary to meet the requirements of the suborbital, low earth-orbit, and balloon flight projects. It provides new payload development, timing, command, radar and telemetry tracking, and Science Data Products. The Branch develops project unique electromagnetic compatibility requirements and generates the criteria and test approach needed to insure the electromagnetic compatibility of instrument and spacecraft hardware. It provides Electrical Leads to Science Principle Investigators to support unusual, quick reaction missions or proposal development.

**Paul Bryant**
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**Laura Milam**
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**Flight Dynamics Analysis Branch (FDAB) —** The FDAB provides various support functions to the flight projects and scientists throughout a mission's lifetime. The FDAB provides these functions from the early mission support of analyzing mission requirements and the development of ground and onboard systems that will be used for launch and routine operations.

The FDAB analysis process is divided into several major areas of technical expertise: attitude determination and control, navigation, mission design and trajectory control, and the vehicle and network areas. The attitude determination and control area is responsible for the analysis, development, operational support and 'verification' of the mission's attitude estimation and pointing system, and the on-board sensors related to attitude determination. The navigation, mission design, and trajectory control area is responsible for the analysis, operational support and verification of the mission's navigation systems and orbital trajectories. Representatives from these areas work closely with the Project Office, scientists, tracking networks, and the spacecraft manufacturer to ensure that all requirements are met to provide for a nominal Goddard Space Flight Center mission. All areas support advanced research for the analysis and algorithm development of new and innovative operations support.

The attitude determination and control area draws upon experience from several technical disciplines. The areas of special interest include engineering, mathematics, estimation theory, control theory, physics, and classical mechanics. Currently research and analysis items active within the organization include:

- Studies related to analyzing attitude sensor performance and calibrations
- Advanced attitude determination algorithm development and analysis (such as using GPS)
- Advanced estimation techniques for all attitude related topics (such as Kalman Filtering)
- Development of new techniques and algorithms for sensor/instrument calibration
- Studies related to the performance characterization and improvement of attitude control systems

The navigation, mission design and control area draws upon expertise from several technical disciplines. The areas of special interest include engineering, mathematics, physics, estimation theory, and orbital mechanics. Currently research and analysis items active within the organization include:

- Advanced orbit determination algorithm development and analysis (such as on-board or ground processing with TDRS, ground trackers and GPS).
- Development of new targeting techniques and algorithms for trajectory optimization and control (such as lunar swingbys and libration orbits, automated maneuver control, and formation flying)
- Analysis for development of algorithms for generation of orbit related planning products (such as automated acquisition data)
- Advanced estimated techniques for orbit determination (such as KaIman Filtering)

**Thomas Stengle**
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**Software Engineering Laboratory (SEL) —** The Software Engineering Laboratory (SEL) is a cooperative research effort among NASA Goddard Space Flight Center, Computer Sciences Corporation, and the University of Maryland. The SEL studies software engineering process and product improvement approaches within the Information Systems Center. Its primary objectives are to: understand and characterize the environment; assess, refine and infuse new technologies identified as having the potential to improve the environment process; and to package the results of the assessment for the benefit of organization and NASA. Measures of concern (e.g., cost, reliability, cycle-time) are identified by NASA as it determines the short and long-term objectives for its software products. Once these goals are known, the SEL designs experiments which define specific metrics to be captured and analyzed in reaching the organizations objectives. Previous representative areas of study have included object-oriented design, Cleanroom, IV & V, COTS, and testing techniques.

**Howard Kea**
(301) 286-5252

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**Systems, Technology and Advanced Concepts Directorate (STAAC)** — The Systems, Technology and Advanced Concepts Directorate provides end-to-end systems engineering expertise and leadership for the development of space flight mission systems, advanced concepts, and technology. STAAC is responsible for providing Agency-wide management of areas of technology development for Earth-orbiting space missions and for Small Business Innovation Research, and Technology Transfer programs; leading the transfer and commercialization of technologies at GSFC; developing implementation and risk mitigation strategies for the infusion of technologies into programs, missions and projects; and ensuring that technology advancements are carried from concept through final design.

**Orlando Figueroa**
(301) 286-1047

**Michael Ryschkewitsch**
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**Advanced Engineering Environments Office** — This office develops new systems engineering tools and processes for use by NASA spacecraft mission managers, engineers, and developers. The office also leads Goddard's efforts for the Agency's Intelligent Synthesis Environment, a NASA-wide tool and capability development initiative.

The Instrument Systems Analysis Laboratory (ISAL) focuses on individual scientific instruments. This laboratory is being created to provide end-to-end capabilities for modeling, analysis and simulation for Earth and space science remote sensing instruments. Design and analysis tools are integrated to facilitate quick and efficient Structural-Thermal-Optical, jitter, and detailed radiometric, spectrometric, hyperspectral, and interferometric analyses. Performance modeling (physics based functional modeling) and integrated physical or geometric modeling (structural, optical, thermal, etc.) will be accomplished for both performance analyses and for time-domain simulations. This capability allows quick and efficient trade off of instrument concepts and architectures, including cost and performance validation.

**Kris Brown**
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**Bill Hayden**
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**Project Formulation Office** — The Project Formulation Office manages the development of feasible mission concepts, formulation of new projects as directed by NASA's Enterprises, and the Access to Space efforts for GSFC and its customers and partners. Key aspects include mission-enabling activities such as requirements development, concept studies, risk mitigation strategies, infusion of new technologies, project definition, and partnership formulation. This process frequently involves identification of technology needs for future missions, which helps guide NASA and Goddard's technology development activities. The development of these new technologies enable future missions, allows achievement of higher performance, and reduced lifecycle mission cost. Missions currently are in formulation for Space Science, Earth Science, and Human Exploration. Associated technology development includes nano-satellite subsystems, autonomous satellite and ground operations, instrument optics and detectors, inflatable technologies, and advanced data systems.

**Thomas Taylor**
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**Flight Instrument Development Office —** This office provides end-to-end technical management of advanced space and Earth science flight instrument developments. This includes the generation of proposals in response to opportunities, instrument system definition, new mission studies, and instrument implementation. In this role, it is responsible for developing programmatic risk mitigation strategies for the infusion of leading-edge technologies into flight instruments and ensuring that technology advancements are carried from concept through final development. Current technology developments include x-ray, visible, infrared, submillimeter, and microwave components and subsystems that are necessary to enable the scientific measurements.

The Integrated Mission Design Center (IMDC) provides the tools and facilities for a highly interactive concurrent engineering environment. By focussing a resident team of expert engineers and a variety of computer-based simulation models, the IMDC is able to analyze a variety of mission concepts and technology alternatives in a fraction of the time needed to complete a traditional mission study effort. The typical IMDC study involves analysis of spacecraft propulsion, electrical power, mechanical, communications and attitude control systems, as well as orbital dynamics and top-level cost estimating. The IMDC will be in a continuous state of evolution as new analytical tools and technologies are introduced, and existing ones are refined.

**Richard Barney**
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**Suborbital and Special Orbital Projects Directorate (Wallops Flight Facility) —** The Suborbital and Special Orbital Projects Directorate (SSOPD) mission is to provide support to the scientific and technology communities through frequent, low-cost flight project opportunities. These flight projects include sounding rockets, scientific balloons, science aircraft, small orbital spacecraft, and shuttle-based carriers. The major activities conducted by the directorate are:

**Sounding Rocket Program** — This program provides "cradle to grave" support to an investigator by designing and analyzing a mission to meet the science requirements; designing, fabricating, and testing the spacecraft; integrating the spacecraft with a suborbital rocket system; and providing project management and launch operations support from numerous worldwide launch locations.

**Balloon Program** — This program provides the science community with access to the upper atmosphere for extended durations from numerous worldwide locations. The flight projects are conducted by a contractor at the National Scientific Balloon Facility in Palestine, Texas. The SSOPD manages the overall program and performs research and development activities. A major research focus of the program currently underway is the development of balloon systems capable of remaining aloft for approximately 100 days.

**University Class Projects** — This organization is responsible for mission management of spacecraft selected and funded by NASA. This management includes providing technical expertise and in-house capabilities to the Principal Investigator. Spacecraft may fly on the Space Shuttle, expendable launch vehicles, or long duration balloons.

**Spartan Projects** — Spartan provides frequent, low-cost orbital flight opportunities for flying science and technology experiments. The Spartan carrier is a reusable spacecraft bus that is flown aboard the Space Shuttle, deployed on orbit, and retrieved prior to Shuttle landing. This organization is responsible for overall management of missions, including proposal generation, design, development, test, launch, flight operations, and data analysis. New activities include the development of new carriers and Space Station related missions. These projects are managed at the Greenbelt facility.

**Shuttle Small Payloads Projects** — This organization manages the design, development, test, integration, and flight operations of small payload carrier systems that fly aboard the Space Shuttle. The carriers include Hitchhiker, Getaway Specials (GAS), Space Experiment Module, and Complex Self-Contained Payloads (CSCP). These carriers contain science, technology, and education payloads for NASA, other government agencies, educational organizations, commercial entities, or international organizations. These activities are managed at both the Greenbelt and Wallops facilities.

**Aircraft Projects** — This activity utilizes aircraft as a platform to carry scientific equipment, principally in support of Earth Science related programs. The SSOPD provides the project management and engineering necessary to conduct scientific measurements including the integration of experiments on aircraft and modifications of aircraft structures.

**Launch Range** — In support of NASA rocket-based science and technology launch requirements, the SSOPD maintains and operates a launch range. NASA projects include launches of scientific sounding rocket payloads, orbital spacecraft, and new technology vehicles and payloads. This support includes project management, telemetry and radar tracking, communications, range safety, ordnance handling, data reduction, and other support services necessary to a range user. In support of these activities, the SSOPD maintains a Range Control Center, assembly and storage facilities, blockhouses, and rocket launchers. The launch range also supports numerous other users including the Department of Defense and commercial customers. The SSOPD maintains a complete mobile launch range capability for support of launch operations throughout the world.

**Research Airport** — The Wallops airport serves as a supporting resource for organizations conducting aeronautical research. These users include Langley Research Center, the Federal Aviation Administration, the Department of Defense, and commercial industry. The airport has numerous characteristics including textured surfaces for tire research, a water ingestion testing pit, calibration points, arresting gear, and the ability to utilize radar and telemetry ground systems for data acquisition. The SSOPD provides project management support to users by coordinating Wallops resources for the users.

**Bruce Underwood**
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Policy and Business Relations Office

# Jet Propulsion Laboratory

## MISSION

The primary role of the Jet Propulsion Laboratory (JPL) within NASA is the exploration of the solar system, including planet Earth, by means of unmanned, autonomous spacecraft and instruments.

JPL scientists, technologists and engineers engaged in Earth atmosphere and geosciences, oceanography, planetary studies (including asteroid and comet), and solar, interplanetary, interstellar, and astrophysical disciplines. Opportunities for Graduate Student Researchers exist in all technical divisions of JPL. These technical divisions encompass almost all JPL engineering and science resources. Each technical division is concerned with the planning, design, development engineering, and implementation functions relevant to its discipline area. Fundamental to the structure of JPL is the cooperation among the functions of research, science, advanced technology, and engineering of these operating divisions.

## PROGRAM ADMINISTRATOR

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## SYSTEMS DIVISION

The Systems Division performs systems engineering and design integration for all the major projects undertaken by JPL. It also conducts specialized analyses in many disciplines to support these projects.

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**Mission and Systems Architecture —** Includes flight mission architecture development, planning mission timelines to accommodate science requirements, advanced flight mission and system planning, flight project launch approval planning, design of end-to-end information systems, and flight project and information system engineering. Also performs economics, operations research, costing, and mission analyses for a broad spectrum of unmanned and manned space projects and military and civilian ground-based programs. Performs system level design, integration, and development of information systems, including computer hardware and software and large distributed near real time ground data processing. Disciplines include electrical, mechanical, aeronautical, and aerospace engineering, computer science, economics, operations research, and the physical sciences.

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**Navigation and Flight Mechanics —** Includes interplanetary spacecraft trajectory design, launch vehicle trajectory analysis, and software development to support scientific spacecraft trajectory design. Develops the capability to determine very precisely the position and velocity of scientific spacecraft in interplanetary space through radiomemtric and optical techniques. Designs propulsive maneuvers to place spacecraft on correct trajectories, develops software to solve the equations of motion, and conducts scientific studies of relativistic gravity, planetary, comet, and asteroid orbital dynamics, gravitational radiation and planetary masses and gravity fields using spacecraft radio tracking data.

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**Flight Systems Engineering —** Supports JPL flight projects by providing design integration of the total spacecraft system, including its interfaces with the launch vehicle and with its scientific instrument payload. Provides design integration of major instrument systems. Conducts studies and analyses of advanced future spacecraft designs, and analyzes the performance of spacecraft in flight. Also performs planning, management and performance of test, integration and launch activities for major systems, including spacecraft, science instruments, ground data systems and ground support equipment. Conducts research and development for integration and test technologies, and operates and manages JPL's major Spacecraft Assembly Facility.

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**Mission Systems Engineering —** Supports JPL flight projects in the development of plans for the operation of interplanetary spacecraft in flight, in the design of ground data systems for flight operations, and in managing the configuration of large data systems. Develops the software models and detailed sequences to be executed by interplanetary spacecraft, plans the commands required to carry out the sequences, and develops the software that keeps track of the command sequences and that ensures the commands will safely perform the desired functions. Provides support to science activity development and implementation. Conducts research related to planning and sequencing software technology.

**Kent Frewing**
(8l8) 354-6780

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## EARTH AND SPACE SCIENCES DIVISION

The Division conducts a wide-ranging program of research in oceanography, the atmospheres and solid bodies of Earth and other planets, planetary satellites, asteroids, comets, astrobiology, interplanetary medium, solar physics, and astrophysics. Ground-based observations, laboratory measurements, aircraft, balloons, and Earth-orbiting and planetary spacecraft are utilized. Extensive laboratory and theoretical research efforts, data analysis, interpretation, and modeling support these observational programs.

**Donald Young**
(818) 354-7442

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**Astrobiology** — The Astrobiology program at JPL is a program strongly based in environmental microbiology and microbial ecology, with a focus on the mechanisms whereby life survives in extreme conditions. The environments of study will be alkaline lakes, cold lakes, dry cold environments, and deep sub-glacial lakes. The studies include field work in these environments, identification of the organisms present, their metabolism, and the potential relationship of these environments and their organisms to extraterrestrial environments that might harbor (or have harbored) life. The ultimate goal is to develop a suite of biosignatures that will allow us to unambiguously identify life in samples on and off Earth, even when the signals of life are very subtle.

**Kenneth Nealson**
(818) 354-9219

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**Oceanography** — Altimetry for determining currents and tides; air-sea interactions including, fluxes of mass, momentum, energy, and chemicals between ocean and atmosphere; determination of marine biomass and ocean productivity; sea ice dynamics and influence on climate variability; global surface temperature measurements; surface driving forces and wave propagation derived from radar observations.

**Lee-Leung Fu**
(818) 354-8167

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**Earth Atmosphere** — Laboratory research, field measurements, and data analysis to understand the chemistry of stratospheric ozone; monitoring of long-term trends in important minor and trace constituents; extraction of meteorological parameters from satellite data, including temperature profiles, humidity, clouds, winds, and pressure.

**James Margitan**
(818) 354-2170

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**Planetary Atmospheres** — Observations from ground-based telescopes and analysis of spacecraft data to determine composition, structure, and dynamics; long-term study of seasonal and inter-annual variability; global mapping; synthesis of information to determine physical processes and state of the atmospheres.

**Jay Goguen**
(818) 354-8748

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**Earth Geoscience —** Characterization of exposed rocks, sediments, and soils on the Earth's surface to understand the evolution of the continents; examination of the state and dynamics of biological land cover for assessment of the role of biota in global processes; tectonic plate motion; volcanology; paleoclimatology.

**Ronald Blom**
(818) 354-4681

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**Planetology —** Observations of the surface of the inner planets, the satellites and rings of the outer planets, asteroids and comets across the spectral range from ultraviolet through active and passive microwaves; studies of meteorites and cosmic dust; theory and modeling relevant to the origin and evolution of the solid bodies of the solar system; development of approaches to the detection and characterization of solar systems around other stars.

**Bruce Banerdt**
(818) 354-5413

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**Space Physics —** Mapping of the magnetic fields of the Sun and planets and their time variations; structure and dynamics of the solar wind; interactions of solar fields and particles with the magnetic fields and outer atmospheres of Earth and planets. Development of space plasma instruments.

**Bruce Goldstein**
(818) 354-7366

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**Astrophysics —** Galactic and extragalactic astronomy and the development of instrumentation in the infrared, visible, and gamma-ray regions of the spectrum, measurement of the cosmic microwave background, composition and chemistry of interstellar clouds, origins of planetary systems, gravitational wave physics and the detection of gravitational waves.

**William Langer**
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## TELECOMMUNICATIONS SCIENCE AND ENGINEERING DIVISION

**Astrophysics —** Observational and theoretical research into the nature of radio emissions from quasars, galaxies, and stars.

**Robert Preston**
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**Planetary Atmospheres and Interplanetary Media —** Experimental and theoretical research investigations based on the use of spacecraft radio signals to probe planetary atmospheres and the interplanetary/solar plasma.

**Richard Woo**
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**Planetary Dynamics —** Determination of orbital, rotational, or atmospheric motions of planets by tracking of spacecraft or balloons associated with the planets.

**Robert Preston**
(818) 354-6895

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**Lunar Dynamics —** Use lunar laser ranges to measure lunar rotation and orbit for the study of lunar science and relativity theory.

**James Williams**
(818) 354-6466

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**Geodynamics —** Experimental and theoretical investigations of global and regional phenomena using the modern space geodetic techniques of lunar laser ranging, Very Long Baseline Interferometry (VLBI) and the Global Positioning System (GPS).

**Jean Dickey**
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**Information Theory and Coding —** Theoretical research in information theory, channel and source coding with special emphasis on deep space communications. Design of codes, decoding architectures, and data compression systems, including on-board science processing. Combined coding and modulation for bandlimited channels. Evaluation of end-to-end performance of the communication system.

**Fabrizio Pollara**
(818) 354-4287

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**Optical Communication** — Theoretical and experimental research involving free space laser communications systems, components, and techniques, and including such item lasers, detectors, modulators, signal design, large telescope design, spatial and temporal acquisition and tracking, detection strategies, and channel coding.

**Hamid Hemmati**
(818) 354-4960

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**Frequency Standards Research** — Experimental investigations in the area of quantum electronics and quantum optics, including ion and atom trapping and tooling, for the development of ultra-stable sources of microwave and optical reference frequencies.

**Lute Maleki**
(818) 354-3688

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**Planetary Radar Astronomy** — Experimental and theoretical research in planetary surfaces, atmospheres, and rings (including geology, spin dynamics, and scattering properties of rings and cometary debris swarms) using the ground-based Goldstone radar system, the Very Large Array, and Arecibo Observatory to form images of terrestrial planets, asteroids, and comets.

**Martin Slade**
(818) 354-2765

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**Radar Remote Sensing of the Earth** — Experimental and theoretical investigations in remote observation of the Earth's surface through radar scattering properties, for example, polarization and interferometry to determine the structure and motion of regions of interest.

**Yunjin Kim**
(818) 354-9500

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**Microwave Antenna Holography** — Experimental and theoretical research in microwave antenna holography and related topics. These include: phase retrieval, prescription retrieval, antenna design and optimization techniques, and advanced development of antenna measurement and instrumentation.

**David Rochblatt**
(818) 354-3516

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**Atmospheric Remote Sensing —** Experimental and theoretical investigations of water vapor in the Earth's atmosphere. Emphasis on providing active calibration of the delay imposed on radio and optical remote sensing techniques.

**George M. Resch**
(818) 354-2789

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## AVIONIC SYSTEMS AND TECHNOLOGY DIVISION

**Advanced Spacecraft Control Systems —** System architectures, sensors, actuators, and algorithms for autonomous rendezvous, docking, aerobraking, and landing. Development of concepts to enable high bandwidth control of flexible space structures and to provide active space control. Development of concepts to enable space interferometry missions.

**Tooraj Kia**
(818) 354-5165

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**Multi-mission Spacecraft Avionics Core —** Develop and design an avionics core for instruments and interplanetary spacecraft. Establish requirements and minimum core architecture that is scalable. Architecture must allow reuse of software, documentation and development tools across multiple missions.

**Tooraj Kia**
(818) 354-5165

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**Spacecraft Autonomy** — Architecture for robust and testable highly autonomous spacecraft. Includes supervisory or goal-directed ground-based control. On-board task planning and scheduling. Robust, fault-tolerant on-board sequence or plan execution. Autonomous position determination, autonomous guidance laws. Autonomous attitude maneuvers and propulsive maneuvers, autonomous target acquisition and tracking, autonomous spacecraft resource management, autonomous fault detection, isolation, and recovery. Operations approaches for highly autonomous systems. Testing approaches for highly autonomous systems.

**Douglas Bernard**
818-354-2597

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**Autonomous Control Systems** — Development of advanced control methods and concepts for autonomous spacecraft stabilization, pointing and tracking. Integration of miniature/feature trackers, gyros and advanced metrology systems. In-flight identification, estimation and control strategies for space interferometers. Development of a new generation of control design, modeling, and simulation tools.

**David Bayard**
(818) 354-8208

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**Precision Landing** — Research in advanced autonomous control concepts, architectures, design methodologies and algorithms for high precision landing on large and small planetary bodies. Image-based pointing and control.

**Fred Y. Hadaegh**
(818) 354-8777

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**Formation Flying Control** — Research in advanced control architectures, algorithms, simulations and testbeds for autonomous high precision control of formation flying of spacecraft. Design of optimal maneuvers for targeting and formation reconfigurations. Advanced algorithms and design concepts for autonomous multiple bodies rendezvous and docking with emphasis on image based pointing and tracking.

**Fred Y. Hadaegh**
(818) 354-8777

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**Formation Flying of Multiple Spacecraft** — Research in optical and RF formation flying sensors, testbeds, along with integration and testing for multiple spacecraft formations (including rendezvous and docking) in Earth orbit and deep space.

**Kenneth Lau**
(818) 354-9749

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**GPS Based Attitude Determination** — Performance improvement through active multipath suppression and passive multipath mitigation (e.g., configuration, RF absorbing materials).

**Kenneth Lau**
(818) 354-9749

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**Control of Inflatable Antennas** — Research in modeling, pointing control, vibration control, and shape control of large, inflatable systems. Analysis and control of optical/RF performance and structural dynamics.

**Sam Sirlin**
(818) 354-8484

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**Interferometer Technologies —** Development and design of high fidelity optical and structural component models for multi-disciplinary modeling (thermal, structures, controls and optics). Control systems with massively distributed sensors and actuators, innovative high bandwidth controls, fault detection and recovery.

**Sanjay Joshi**
(818) 354-0451

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**Interferometric Metrology Systems** — Development and testing of space-qualifiable systems and system components for interferometric metrology applications. Frequency stabilized laser sources, integrated optics components, fiberoptic components.

**Serge Dubovitsky**
(818) 354-9796

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**Precision Mechanisms and Motion Sensing** — Innovative devices for rotating and displacing optical components to high precision and at high bandwidth (e.g., for active and adaptive optics and optical interferometry), and devices for sensing such motion.

**Linda Robeck**
(818) 354-0008

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**Autonomous Vehicles —** Real-time path planning in uncertain terrains; locomotion and mobility, computer vision for rover control, and combined mobility and manipulation.

**Brian Wilcox**
(818) 354-4625

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**Rover Technology —** Rover navigation in uncertain terrains, rover localization, sample acquisition from small rovers, intelligent rover based science experiments, and web-based operator interfaces.

**Dr. Samad Hayati**
(818) 354-8273

**Robot Arm Control** — Research in advanced manipulator control, adaptive arm control, control of redundant arms, cooperative multi-arm control, force and impedance control, motion planning and control of robotic vehicles, robot control architectures, task-level control, sensor-based motion planning and control, intelligent control of robots.

**Homayoun Seraji**
(818) 354-4839

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**Robotics Man-Machine Systems** — Development of controls, sensing, manual and graphics-based user interfaces for telerobotic operations and telepresence. Applications to robotic space servicing and exploration and medical robotics.

**Homayoun Seraji**
(818) 354-4839

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**Optical/Digital Pattern Recognition** — Research and technology development in algorithm, architecture, hardware implementation of pattern recognition systems using both optical and digital implementations. Processing methodologies of interest include: correlation, wavelet transforms, mathematical morphology and neural networks. Hardware implementations will be emphasized on Fourier optics and customized DSP.

**Tien-Hsin Chao**
(818) 354-8614

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**Machine Vision Systems** — Development of algorithms for visual shape and motion estimation, object recognition, and pose estimation for applications in space flight and planetary exploration. Such applications include autonomous rendezvous and docking, autonomous landing, robotic maintenance of earth-orbiting spacecraft, and planetary rovers. Also interested in development of advanced imagers and high performance, low power, onboard computing hardware for these applications

**Larry Matthies**
(818) 354-3722

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**Vis/UV/X-ray Sensor Technology** — Investigation of advanced materials and devices for the detection of electromagnetic radiation in the visible through low-energy x-ray wavelength regime. Development of high-performance backside-illuminated charge-coupled devices, rejection and anti reflection coatings, and space science instrument concepts. Research on wide bandgap semiconductor materials for solar-blind detectors.

**Siamak Forouhar**
(818) 354-4967

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**Infrared Detectors —** Investigation of III-V based new device structures for infrared radiation detection. The research involves studying intersubband absorption, interband absorption and carrier transport properties in III-V superlattices and multi-quantum well structures.

**Sarath Gunapala**
(818) 354-1880

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**Advanced In-Situ Sensors and Devices —** Design, research, and development of advanced miniaturized sensors for planetary exploration and earth monitoring. Technologies under development include physical sensors (micromachined seismometers, hygrometers, electron probes, micro Lidars and dust analyzers, geochronological dating methods, pressure transducers, IR thermal detectors) and chemical sensors (Micro-NMR, capillary electropheresis on a chip, amino acid and fatty acid detection, X-ray diffraction and micro-spectroscopic analysis). This also includes the systems necessary for sample collection, calibration, and data collection.

**Timothy Krabach**
(818) 354-9654

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**MEMS Technology —** Research and development in micromachining technology, modeling, reliability, and integration. The microfabrication facilities in MDL are used extensively to develop innovative fabrication approaches to demonstrate next-generation micromechanical devices for a variety of micro-sensors and micro-actuators.

**William C. Tang**
(818) 354-2052

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**Electric Power Research and Engineering —** Development of lightweight, high-power fuel cells; high efficiency thermal-to-electric conversion, including use of high temperature solid electrolyte electrochemical cells (AMTEC) and thermoelectrics; high-efficiency photovoltaic conversion; high energy batteries including lithium technologies; and high-density power microelectronics.

**Perry Bankston**
(818) 354-5197

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**Integrated Space Microsystems** — Research and development of advanced microelectronics computing and avionics systems technologies, including: Semiconductor technologies for scaled voltage, power, and feature size; Ultra Low Power devices, architectures, and systems; Radiation Tolerant electronics, architectures and systems design; Advanced flight computer design, performance modeling, benchmarking and evaluation; Memory systems for both volatile and non-volatile storage (SRAM/DRAM/Flash, Holographic storage, etc.); Low Power I/O architectures; high-speed interconnect networks; commercial off the shelf architectures for low-cost system applications; Fault Tolerant systems, including hardware and software fault-tolerance using off-the-shelf components; Modeling and analysis of FT systems. Design Automation techniques for Design for Testability and Built In Self Test; Advanced Microelectronics Packaging, such as chip stacking in 3D, MCMs, and MCM stacking in 3D; Collaborative engineering, integration and testing.

Integrated systems on a chip, including integrated power management, data storage and processing, sensor technology, and RF communication technology. Advanced computing concepts, including quantum computing, quantum dots, innovative computer architectures, biologically inspired systems, molecular nanotechnology, atomic scale technology, etc.

**Leon Alkalai**
(818) 354-5988
Fax: (818) 393-5007

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**Advanced Multi-Mode Avionic Design** — Development of advanced designs that incorporate analog/digital optoelectronics and/or RF on one substrate. Development of the design tools necessary for such devices. Development of specific avionic equipment utilizing such devices (I/O interfaces, switching circuitry, etc.).

**Mark Underwood**
(818) 354-9731
Fax: (818) 393-4944

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**Data Storage Technology —** Investigation of hybrid magnetic-semiconductor memory devices for the development of memory and data storage modules for space applications. Development of design, simulation and experimental capabilities to validate technologies for space data storage applications. Investigation of magneto-optical and optical data storage technologies, including holographic data storage, for space mass-storage applications.

**John Klein**
(818) 354-2603

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**Magnetic Device Technology** — Investigation of magnetic devices such as microinductors, micro-transformers, and magnetically actuated devices for space applications.

**John Klein**
(818) 354-2603

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**Concurrent Processing Using Analog/Digital Hardware** — Research in architectures and algorithms related to neural networks, fuzzy logic, genetic algorithms, cellular automata, evolvable hardware, and other similar VLSI-based armlog and digital parallel processing devices.

**Taher Daud**
(818) 354-5782

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**Advanced Computing Technologies** — Research in algorithms, architectures, and technology related to artificial neural networks, fuzzy logic, genetic algorithms, evolvable hardware, expert rule processor, and other similar VLSI-based analog and digital parallel processing devices. In addition, research in biocomputing architectures and technology development are also of interest. Applications to target and image processing, on-board adaptation, 3-dimensional VLSI architectures, and similar high speed and low power multichip module technology approaches are of keen interest as well.

**Taher Daud**
(818) 354-5782

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**Neural Network Algorithms** — Advanced neural algorithms for spacecraft control, autonomous rendezvous, docking, and landing. Development of feature extraction and tracking algorithms for small body spin vector and shape estimation. Application of neural networks to multi-sensor integration.

**Benny Toomarian**
(818) 354-7945

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## MECHANICAL SYSTEMS DIVISION

The Mechanical Systems Division carries out research in propulsion, cryogenics, structures, mechanical systems, materials, and thermal sciences. Research opportunities exist in materials with unique electro-mechanical and optical properties, active control of structural shape and vibration, inflatable structures, chemical sensors, cryogenic cooling systems including sorption coolers and integration of mechanical coolers with instruments, advanced superfluid helium cryostats, electric propulsion, autonomous mobility systems and remote sample acquisition.

**Thomas Luchik**
(818) 354-3165

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## INFORMATION SYSTEMS DEVELOPMENT AND OPERATIONS DIVISION

The Information Systems Development and Operations Division performs research, development, planning, and operations related to ground-based information systems for spacecraft missions and other tasks in the national interest. Activities include:
(1) mission operations engineering, technology, control, and data management,
(2) information systems engineering, technology, and services,
(3) ground data systems applications engineering and development,
(4) space and institutional networks engineering, and
(5) advanced information systems technology development and applications.

Research areas include:
(1) advanced automation for spacecraft and ground system operations,
(2) machine learning and applications,
(3) simulation, modeling, and expert systems,
(4) high-rate, high-capacity distributed information systems,
(5) software productivity and reliability,
(6) high-performance computing and supercomputing, and
(7) low-cost mission operations.

**David Atkinson**
(818) 393-2769

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## OBSERVATIONAL SYSTEMS DIVISION

The Observational Systems Division is responsible for the conception, design, engineering, development, and implementation of a variety of scientific instrumentation for space flight applications. Key elements in the division are digital image processing research and development for space science, environmental and Earth resources applications, and the management and archiving of science data.

**Mary Bothwell**
(818) 354-2399

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**Imaging and Spectrometry Systems** — Technology development and application for advanced imagers, spectrometers and analytical instruments for remote sensing and in-situ environments. Provides technology and tools for end-to-end modeling/Simulation of missions and experiments. Develops advanced algorithms and software for scientific data visualization, analysis and modeling calculation, including state-of-the-art work in parallel and network computing. The Section is in the forefront in research and advanced development of instruments for in-situ analysis of chemical species including mass spectrometry, scanning electron microscopy, X-ray diffractrometry.

**Ray Wall**
(818) 354-5016

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**Microwave, Lidar, and Interferometer Technology —** Conceive, design, implement and calibrate scientific optical interferometers, microwave through submillimeter wave passive radiometers, and Lidar observational systems. This includes advanced research and technology development and prototype instrument development to support near term and future remote and in-situ space missions. Development opportunities for new instrument systems with the user community.

**Dan Coulter**
(818) 354-3638

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**Space Instruments Implementation —** Conception, design development and implementation of remote and in-situ sensing systems to enable both NASA and other agencies space science investigations and observations. Specifically, the lead organization responsible for space flight hardware implementation of observational systems. Performs engineering development, test and calibration for flight instrument systems, including optical imaging and spectrometer systems, microwave and submillimeter radiometer systems, and in-situ chemical analysis and electron microscopy instruments for remote and landed science investigations.

**Valerie Duval**
(818) 354-5786

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**Science Data Processing Systems —** Develops and applies image processing techniques to the display, analysis, and interpretation of image and image-related data. Utilizes engineering and artificial intelligence to develop automated and semi-automated schemes for data interpretation. Performs research and development in image processing. Also develops and applies specialized software, hardware, and systems architectures to increase the speed of computationally intensive functions on large data sets. Provides image processing and analysis support to the flight projects, imaging teams, and the science community.

**Sue Lavoie**
(818) 354-5677

**Science Data Management and Archiving —** Design, develop and operate science data systems for producing archive data products from data generated by NASA's observational instruments. Design, develop and operate data catalog and data access systems using DBMS and hypertext based technologies (such as those underlying the World Wide Web). Implement NASA's educational outreach objectives through the development of multimedia-based educational products available on CD-ROMs or on the WEB. Lead in R&D for archive product and distribution technologies such as CD-ROMs and access to massive data archives.

**Yolanda Oliver**
(818) 393-2575

## ENGINEERING AND MISSION ASSURANCE DIRECTORATE

**Microelectronic Radiation Hardness Assurance —** Work is focused on research and testing of the reliability of electronic parts in the harsh radiation environments experienced by NASA spacecraft. Current activities include investigations into radiation effects in electronics and photonics caused by heavy ions characteristic of galactic cosmic rays, electrons, protons and 60Co gamma rays; simulation of single event effects (SEE) by 252Cf; and radiation testing of parts for NASA flight projects. In addition, evaluations are performed of test methodologies and process technologies used to produce reliable, radiation-tolerant microelectronic circuits such as application specific integrated circuits (ASICs), field programmable gate arrays (FPGAs) and large memories (SRAMs, DRAMs).

**Charles Barnes**
(818) 354-4467

**Systems Assurance —** Systems Assurance conducts research in wide range of areas concerned with the quality and reliability of spacecraft systems. Research opportunities exist in the modeling, analysis, and simulation of the natural and induced spacecraft mission environments and of their effects on spacecraft systems, subsystems, and individual components. Software reliability analyses and metrics definition are other areas of rapidly growing research. Specific issues associated with software, spacecraft sensors, control systems, and other flight hardware are of interest.

**A. G. Brejcha**
(818) 354-3080

**Reliability Engineering —** Develops reliability and environmental design, analysis, and test requirements for all JPL flight projects. Reliability activities include electrical and mechanical analyses and environmental requirements activities include: thermal, dynamics, electromagnetic compatibility, and natural space environments. Natural environments include solar and planetary thermal conditions, micrometeoroids and space debris, and space plasma. Induced environments include vibration, acoustic, pyrotechnic shock, and thermal loads, electromagnetic effects, spacecraft charging, etc.

**J. F. Clawson**
(818) 354-7021

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**Software Product Assurance —** Software Product Assurance has the objective to help ensure the operational integrity of the software developed for JPL systems, and evaluates the operational requirements, the acceptability and readiness of all software prior to delivery. It also researches advanced techniques in software engineering, human computer interface, software safety, and metrics, and performs technology transfer to techniques tailored for the JPL and NASA environment to improve the quality of software within JPL and NASA.

**R. Santiago**
(818) 354-2452

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## MULTIMISSION OPERATIONS SYSTEM OFFICE (MOSO)

The Multimission Operations Systems Office integrates the development of hardware and software tools to provide efficient and effective multimission operations systems and services to JPL's planetary science projects in order to minimize the cost of mission operations and data analysis. These systems and services include spacecraft analysis and navigation, mission planning and sequencing, science analysis, mission control and data management, computers and communications, and telemetry.

**Terry Linick**
(818) 354-3161

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**HPCC/Earth and Space Sciences (ESS) Project —** JPL is interested in research which will lead to new parallel computational methods for distributed memory supercomputing architectures. Areas of particular interest include parallel visualization and analysis of massive data sets, methods for writing portable parallel applications and algorithms, performance optimization, and novel parallel numerical techniques. This work is in support of ESS Grand Challenge science applications, which include multi-disciplinary modeling of Earth and space phenomena, and analysis of data from remote sensing instruments.

**Robert D. Ferraro**
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# Lyndon B. Johnson Space Center

## MISSION

The mission of the Johnson Space Center is the expansion of a human presence in space through exploration and utilization for the benefit of all. The Center is also responsible for leadership in the field of astromaterials. JSC is the Center of Excellence for Human Operations in Space. This means that JSC provides national leadership and technological preeminence in those capabilities and technologies which support human operations in space. Principal areas include:

Human spacecraft and habitat design and development
Human space life sciences
Flight crew operations
Mission operations and training
Planetary surface systems for human operations

Astromaterials collections, curation, and analysis JSC is the Lead Center for Space Shuttle Program, International Space Station Program, Space Operations, Biomedical Research and Countermeasures Program, and the Advanced Human Support Technology Program. Agency-wide assignments include Extravehicular Activity (EVA), Robotics Technology Associated with Human Activities, Space Medicine, Technology Utilization on International Space Station and Exploration Mission Planning and Design.

## PROGRAM ADMINISTRATOR

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Houston, TX 77058
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## ENGINEERING

**Advanced Life Support Systems** — Current research involves development of regenerative human life support systems for future long duration space missions. Such systems will consist of components which utilize both physicochemical and biological processes to perform the life support functions. Included in these functions are air revitalization, which includes carbon dioxide removal, oxygen generation, and trace gas contaminant control. Water recovery functions include urine treatment, hygiene water processing, and potable water polishing. Food production functions involve crop production using both hydroponics and solid substrate culturing systems as well as automated/robotic systems for plant production. Resource recovery from solid wastes involves such processes as incineration and pyrolysis, and degradation with bacterial bioreactors. Thermal control research areas include light weight, high efficiency heat pumps and unique heat rejection devices to aid in room temperature heat rejection for advanced missions; theoretical studies and analysis techniques for advanced two phase thermal management systems; and automated monitoring and control, and fault detection methods for advanced two phase thermal management systems. Additionally, integration of these systems into a functioning regenerative life support system via highly automated control and monitoring systems is critical to current development efforts.

Research opportunities exist in chemistry, physics, horticulture and plant physiology, soil science, water chemistry, and environmental, chemical, biological, mechanical, computer, and systems engineering disciplines. Opportunities exist for studies of dynamic computer analysis and simulation methodology for hybrid physicochemical and biological systems and development of mathematical models of candidate processes to be integrated into regenerative life-support systems.
For additional information, see: http://pet.jsc.nasa.gov/.

**D. L. Henninger**
(281) 483-5034
dhennin1@ems.jsc.nasa.gov

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**Guidance Navigation and Control —** Research opportunities exist for development of technologies supporting definition, evaluation and development of guidance navigation and control systems for space flight programs.

**Aldo Bordano**
aldo.j.bordano1@jsc.nasa.gov

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**Integrated Design and Simulation Environments —** Define integrated simulation architectures that will allow for dynamically interfacing of multiple simulations and hardware elements across a Wide Area Network (WAN) and keep them synched. For example, guidance, navigation and control (GN&C) flight software is running in one building and the reaction control jets are set-up in another. Instead of moving the two pieces to a common location and then integrating them, create an architecture that would allow the GN&C flight software to run closed-loop while separated in different locations.
Define technology for integrated design environments that allow design tools to be used across multiple platforms and facilities. Create multi-discipline design architectures that allow design tools from different disciplines, developed for different platforms, and in different geographic environments to function as an integrated unit.

**Dave Petri**
david.a.petri1@jsc.nasa.gov

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**Landing Hazard Avoidance —** Design a landing hazard avoidance system for spacecraft landers. Selected landing sites may exhibit hazards such as slopes, ravines, rocks, etc. which should be detected and avoided autonomously. Development of sensor systems, actuator requirements, avoidance maneuver guidance and control algorithms, and landing performance assessment is required. Systems should be demonstrated using simulation and subscale flight tests. Sensitivity analyses to system errors and environmental dispersions should be performed.

**Bedford Cockrell**
bedford.f.cockrell1@jsc.nasa.gov

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**Parafoil Performance —** Research to investigate and determine the aerodynamic stability characteristics for a parafoil and payload system of large scale applicable to spacecraft landing. Of particular interest are attitude damping derivatives, as well as the roll coefficients due to sideslip and yaw rate. Approaches may include literature searches, analytical techniques, subscale ground testing, and/or flight testing. Subsequent evaluation of the longitudinal and lateral-directional dynamic modes of the typical large scale parafoil-payload system should be pursued to determine stability characteristics, flap input response and gust response dynamics. Research opportunities also exist in the technical field of aerodynamics as applied to the modeling of the opening process of ram-air lifting parachutes. The research will include developing an analytical math model describing the canopy opening inflation process for each of several reefing stages. The analytical model will be developed in parallel with complimentary wind tunnel and scaled model flight tests. Technologies involved include aerodynamics, flight mechanics, fluid dynamics, microsensors, structures, aeroelasticty, ground and flight testing, computer coding, and computational fluid dynamics. The math model produced will be used to predict the opening process, to define optimum canopy characteristics, and to establish constraint boundaries.

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**Rick Barton**
richard.l.barton1@jsc.nasa.gov

**Advanced Flight Control —** Develop the algorithms, sensor requirements, and actuator requirements for a robust flight control system for use for advanced mission and system designs for Human Exploration of Space. Using advanced techniques such as neural networks, adaptive techniques, or learning algorithms, design a flight control system for proposed vehicles capable of handling large environment uncertainties. These systems include vehicles using low thrust ion or plasma thrust as well as high performance powered and atmospheric flight.

**Mark Hammerschmidt**
mark.m.hammerschmidt1@jsc.nasa.gov

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**Nanotechnology —** Opportunities exist to research applications and bulk production of single-walled carbon nanotubes. Revolutionary designs and concepts are sought for using the extraordinary properties of nanotubes in areas such as high strength materials and composites, energy storage, nanoelectronics, and thermal protection, among others. These ideas should focus on space applications for long duration missions. Possible bulk production techniques may include electric arc, gas phase, or solar heating as continuous growth methods. Also of interest are growth of continuous aligned nanotubes for applications such as composites.

**Brad Files**
(281) 483-5967
brad.files@jsc.nasa.gov

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**In-Situ Resource Utilization (ISRU) —** The concept of "living off the land" by utilizing the indigenous resources of the Moon, Mars, or other potential sites of robotic and human exploration is called In-Situ Resource Utilization (ISRU). The chief benefits of ISRU are that it can reduce both the cost and the risk of robotic and human exploration by decreasing Earth launch mass and by increasing self sufficiency and surface mobility. The research area includes: (1) collection, separation, and conditioning of in-situ atmospheric, soil/rock, and drilled resources; (2) manufacturing of propellants, fuel cell reagents, and life-support gases and water; (3) collection, liquefaction and/or compression, storage, and transfer of manufactured fluids; and, (4) sensors and software to enable autonomous control of ISRU resource and chemical processing activities.

**Gerald B. Sanders**
(281) 483-9066
gerald.b.sanders1@jsc.nasa.gov

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**Fluid & Vehicle Attitude Control Systems —** Attitude control systems research in the areas of: (1) low gravity earth storable and cryogenic fluid behavior, acquisition, and fluid quantity/flow gauging; (2) pulsing engine design, combustion modeling, and stability analysis; (3) high temperature combustion compatible materials; (4) on-orbit component and system health monitoring; and (5) high performance/long life fluid control components and sensors.

**Eric Hurlbert**
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eric.a.hurlbert1@jsc.nasa.gov

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**Electro-Mechanical Systems (EMAs) —** Research into electro-mechanical systems (EMA) for aerodynamic surface control, mechanical system actuation (i.e. doors, umbilicals, etc.), fluid component actuation, and electrical auxiliary power units for hydraulic systems. This research includes high performance electrical motors, controllers, gear trains, fault tolerance, and associated instrumentation.

**Landon Moore**
(281) 483-9002
landon.moore1@jsc.nasa.gov

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**Electrical Power Systems —** Research area includes electrical power generation (energy conversion), energy storage, and electrical power distribution and control. Specific topics may include: (1) safe application of high density, long life, battery chemistries for manned spacecraft; (2) high current density, long life fuel cells for manned spacecraft applications; (3) specification of stability requirements on source and load converters for large, manned spacecraft regulated power distribution systems, including topologies.

**Thomas L. Davies**
(281) 483-9040
thomas.l.davies1@jsc.nasa.gov

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**Robotic Technologies —** Development of emerging robotic technologies, such as (1) robotic end effectors and manipulators with special emphasis on small scale, dexterous and anthropomorphic robots; (2) human-robotic interfaces for telepresence control of robots, including tactile/force feedback techniques, helmet mounted vision displays, stereoscopic vision displays, and visual and non-visual techniques for following human operator input commands; (3) robotic control software including force/torque feedback, adaptive control, grasping techniques and multi-arm control (for both kinematically sufficient and redundant systems); (4) robotic sensors including contact and proximity sensors for collision detection and avoidance, limiting forces, mapping, etc.; and (5) machine vision and perception including pattern recognition, feature extraction, pose estimation, object tracking, image registration, visual inspection, and landmark navigation. Application of these technologies will be applied to current technology projects including the development of free flying robotic inspection space vehicles, dexterous anthromorphic maintenance and servicing robots and robotic assistants to suited astronauts during planetary science exploration.

**Edith C. Taylor**
(281) 483-1527
edith.c.taylor@jsc.nasa.gov

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**Intelligent Systems for Robotics —** Development of intelligent systems technologies to support the design, development and operation of space robotic systems, such as (1) Computer Software Architectures to Support Intelligent Robotic Systems for

Human/Robot Teams In Space; (2) Realtime Intelligent System Monitoring and Control; (3) Failure Detection, Diagnosis and Reconfiguration; (4) Intelligent System Modeling and Analysis; (5) Automated Design Knowledge Capture; (6) Automated Planning and Scheduling; (7) Fault Tolerant Robotic Control and Adaptive Control of Multimodal High Degree of Freedom and Nonlinear Systems; (8) Intelligent Pattern Recognition and Trend Monitoring; (9) Realtime Expert Systems; and (10) Adaptive and Intelligent Control (including Machine Learning, Neural Networks, Fuzzy Logic). Application of these technologies will be applied to current technology projects including the development of free flying robotic inspection space vehicles, dexterous anthromorphic maintenance and servicing robots and robotic assistants to suited astronauts during planetary science exploration.

**Robert Savely**
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robert.t.savely1@jsc.nasa.gov

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**Flow Diagnostics —** Flow diagnostics and measurement techniques are being developed for both flight and high-enthalpy arc jet flows used for thermal-protection system testing. Some techniques of interest for arc diagnostics are laser-induced fluorescence (LIF), LIF anemometry, emission spectroscopy, laser-Raman scattering, and gas-sampling probes with mass spectrometry. An understanding of flow fields is required for gas/surface interaction studies, including surface catalytic atom recombination and the associated diagnostics of the excited molecules produced. Johnson Space Center has a 10 Mw arc tunnel facility with some laser and spectroscopic diagnostic equipment. More instrumentation for the facility is being planned.

**CD Scott**
(281) 483-6643
c.d.scott1@jsc.nasa.gov

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**Aerothermodynamics —** RESTRICTED ELIGIBILITY: This research is open only to US citizens and Legal Permanent Residents.

Aeroheating to high-speed re-entry and aerobraking vehicles depends significantly on nonequilibrium thermal and chemical rates. Included is the need to understand the kinetics of nonequilibrium radiation in shock layers and in wakes. Techniques for coupling of ablating surfaces with the external flow are needed. Engineering assessment techniques and detailed, physically accurate models require study and development. Physical data such as chemical reaction rates in multitemperature nonequilibrium flows are of interest; transport properties for reacting and partially ionized gases are needed. The chemistry and aerodynamics of the Martian atmosphere is also of interest. Models for catalytic atom recombination on surfaces also need to be developed for both air and the Martian atmosphere. CRAY, SGI, and HP workstation computer systems are available for computations.

**CD Scott**
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**Tracking and Communications —** Research opportunities exist for the following areas of interest: optical and RF sensor systems for autonomous landing and hazard avoidance; digital transmitters and receivers; MMIC distributed array antennas; multi-beam and high-gain electronically steerable antennas; high-rate, free space optical/laser communications systems with ultrahigh convergence and precision acquisition and tracking capabilities; wireless instrumentation systems; space applications of global positioning system capabilities; space to ground HDTV; and orbital debris detection and tracking.

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**Communications and Tracking System Design —** RESTRICTED ELIGIBILITY: This research is open only to US citizens and Legal Permanent Residents.

This research task will involve the design of end-to-end communications and tracking systems for use in a growth Space Station and lunar/Mars/Earth links. These systems will require many types of communications links carrying scientific data, as well as voice, television, and text and graphics. The tracking requirements will include rendezvous radar, traffic-control radar, proximity-operations radar, and automatic-docking measurements.

The techniques/systems to be considered include (1) radio-frequency interference/electromagnetic interference mitigation, (2) digital voice/High Definition television data processing and distribution, (3) voice recognition synthesis, (4) multiple-function/multiple-beam antenna configurations and waveguide arrays, (5) frequency-reuse and spectrum-efficient modulation schemes, (6) automated vehicle-terminal guidance systems, (7) multiple-object radar-tracking techniques, and (8) programmable transceivers.

Candidate designs have been suggested by NASA and several industries. The research under this task will concentrate on identifying an optimum systems design involving technology/techniques in communications/tracking hardware and signal processing.

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**Millimeter-Wave Technology of Advanced Antenna Systems —** This research task will involve laboratory research and systems analyses of millimeter-wave technology as applied to spaceborne communications and antenna systems. This task is directed towards hardware breadboard design and testing of antennas, and associated front-end (microwave integrated circuits/monolithic microwave integrated circuits) electronics. Applications include multiple-beam antennas for communicating with low-Earth-orbiting satellites or geosynchronous relay satellites and high-resolution, orbital debris radar-tracking antennas.

The results of this research will aid in the design of advanced antenna/electronic systems to be used on future space vehicles and the Space Station.

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**Flight Data Systems —** Research opportunities exist for the following areas of interest: High speed, radiation tolerant avionic systems; micro electronic hardware components to enable light weight, low-power, ultra-reliable avionic systems for long duration manned space missions; application of standards to spaceflight data system architectures; fault-tolerant standards solutions; real-time object-oriented software; application of commercial hardware solutions to space flight environments; radiation characterization analysis hardware; mixed signal ASIC design; fault-tolerant backplanes; and distributed processing for sensor signal characterization of impending failures. Laboratory facilities exist to support real-time software and fault-tolerant research.

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**Advanced Habitats and Habitation Systems —** The physiological and psychological interactions of habitat environment factors such as functional and spatial arrangement, color, patterns, temperature, gravity, and social interaction are being investigated to understand the long term affects on humans for remote and isolated operations for future long duration space missions on the Moon and Mars. The goal is understanding of architectural problems and thus solutions to enhance crew morale and productivity. The human built environment (architecture) has always influenced human emotion and perception of space. For this reason, research is needed to address the built environment in space flight and on the planetary surface. A holistic understanding of early exploration phases to expanded base growth leading to settlement is required. Knowledge of how humans live and work in space is essential for planning space missions and designing equipment. Research is needed on the impact of factors which affect crew performance internal and external of the habitats.

The research area includes advanced habitation and construction technology to enable the Human Exploration and Development of Space Enterprise to meet the demanding environment of faster, better, cheaper. Research on architectural functional and spatial arrangement, color, patterns, temperature, gravity, and social interaction are being sought. Space and planetary habitation, pressure structures and unpressurized shelters are being sought out for innovative design solutions that combine high strength and light weight materials, along with the reliability, durability, repairability, radiation protection, packaging efficiency and life-cycle cost effectiveness. Surface base design, development and evolution is being sought out. Advances in material developments and manufacturing techniques that enable the structure to “self-heal,” and the emplacement, erection, deployment or manufacturing of habitats in space or on the Moon and Mars are considered enabling technologies for the evolution of humans into space and the eventual settlement on Mars. Integration of sensors, circuitry and automated components to enable self-deployment and “smart” structures are considered necessary to allow the habitat to operate autonomously. The objective is to create an advanced habitat that becomes a “living” structure that not only runs autonomously, but also has self-healing capability. A number of technologies and techniques have been proposed that allow the delivery of deployable habitats to space/planet surface or the manufacturing and construction of habitats in space/planet surface. Methods for underground development of habitable structures that meet human space flight requirements. Novel methods of extracting, processing and manufacturing in-situ planet (Moon and Mars) materials for autonomously developing structures that meet human space flight requirements. Novel methods and techniques for fully integrated skin and sensors/circuitry that enables “smart” structures that autonomously detect, analyze, and correct (repair) structural failure. Methods of integrating miniaturization technology into the habitat skin, thus reducing weight and increasing self-autonomy.

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## LIFE SCIENCES

**Nutritional Biochemistry Laboratory Research —** Changes have been noted during spaceflight in the metabolism or utilization of several nutrients, including protein, energy, and minerals and electrolytes. These alterations-observed during both spaceflight and ground-based simulations of spaceflight-appear to be related to several other physiologic changes that occur during spaceflight and thus may indicate shifts in metabolism that affect nutrient requirements.

Research will focus on human nutritional requirements for spaceflight. Areas of particular interest include the consequences of microgravity-induced changes in bone and calcium; the influence of exercise on nutritional requirements; alterations in micronutrients metabolism and requirements during long-term spaceflight; interactions of radiation with nutritional requirements for ascorbic acid, iron, vitamin E, and selenium; and the digestion and absorption of nutrients in space.

The nutritional biochemistry laboratory facility has the capability to analyze substances for all major macronutrients, including amino-acids, and for minerals and vitamins. Standard biochemical procedures are available: gas chromatography, inductively coupled plasma-mass spectrometry high-pressure liquid chromatography, atomic absorption with graphite furnace, and ion chromatography. Research efforts are under way to determine the changes in metabolism at entry into spaceflight, during spaceflight, and recovery from spaceflight to define better the nutrient requirements during spaceflight; and to develop appropriate techniques to measure changes in metabolism during spaceflight. The laboratory is particularly concerned with defining these changes, determining when they may be detrimental to crew members, and in developing appropriate countermeasures for any detrimental changes. When appropriate, research will be directed to the amelioration of spaceflight-induced physiological changes through nutritional countermeasures.
Although Space Shuttle flight-experiment opportunities are available to develop and verify related experimental support protocols, the exposure time is limited to flight duration. A Space-Station human research facility dedicated to life-sciences research is being planned that will provide the necessary long-term-exposure experimental test bed.

The laboratory coordinates its efforts with both intramural and extramural collaborators. Other in-house teams include biochemistry, hematology, immunology, endocrinology, and exercise-physiology laboratories. Clinical studies are conducted using ground-based simulations such as bed-rest research projects.

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**Recycled Water: Chemistry, Disinfection, In-Flight Montoring, and Toxicology —** Water reclamation from urine, wash water, and humidity condensate and reuse for potable and hygiene purposes is considered a key feature of long-duration spaceflight in order to avoid massive launch/resupply penalties associated with on-board drinking and hygiene needs. A variety of primary reclamation technologies and a number of pretreatment and post-treatment schemes to minimize or eliminate contaminants from the product water are being developed. The quality of the product water, particularly organic content, is specific to the unique combination of reclamation processes used. Certification of reclaimed water for direct reuse by humans presents major technical problems not encountered in terrestrial water systems. Because of the direct reuse aspects, aggressive efforts are needed to bridge the gap between the technology development efforts and biomedical requirements in order to verify that reclamation processes that are safe and reliable.

The goals of this activity include the following: (1) determination of the contaminant composition of source and product waters from the variety of reclamation processes being developed under both nominal and off-nominal conditions; (2) development of

analytical procedures to support identification and quantification of the organic constituents in recycled water; (3) development of analytical procedures to measure halogen species in waters, with emphasis on iodine disinfection; (4) development of microgravity-compatible monitoring capabilities that minimize expendable requirements, which will be needed to verify the water quality before it is used; (5) determination of relative toxicity of detected organic constituents and the establishment of respective MCLs; (6) definition of quality specifications for water reclaimed for direct reuse from humidity condensate, urine, and wash water; (7) identification and quantification of disinfection products associated with halogen disinfectants; (8) development of advanced water reclamation and post-treatment technology for organics removal and microbiological control; (9) development of methods for remediating contamination events in spacecraft water distribution systems; (10) development of water potability bioassay techniques for recycled water that are potentially adaptable to in-flight application; and (11) development of an overall plan by which reclaimed water can be certified acceptable for human consumption and hygiene uses.
This activity will be performed in the water-quality laboratory in close association with the toxicology and microbiology laboratories.

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**Immune Responses to Space Flight —** The primary concern of the Space Microbiology Program is to ensure the health, safety, and productivity of astronauts. This requires careful diagnostic evaluation of astronauts and their environments before and after missions. Developing microbiological diagnostic technologies for use during a space mission is another important aspect of maintaining crew health and productivity. Microbial analysis of the air, surfaces, water, food, experimental animals, and payloads is included in the environmental assessment.

The Microbiology Laboratory defines requirements, develops specifications, and evaluates candidate hardware in the areas of clinical and environmental microbiology for use on board manned space systems, including the space shuttle and space station programs.

Intense research areas include developing simple, rapid, and direct methods to diagnose infectious diseases and to determine the effects of different microbial loads on human health in a closed system; investigating the effects of spaceflight on microbial population dynamics, structure, and function; pathogenicity; and susceptibility to antibiotics.

In preparation for longer duration missions, vigorous research focuses on the effect of spaceflight and related factors on the human immune response, particularly the immunology of infectious diseases. Experimental and clinical studies will be used to investigate the effect of spaceflight on the three major arms of the immune system: cellular, humoral, and innate immunity. Specific areas of investigation include neutrophil and monocyte function (e.g., chemotaxis, adhesion), natural killer cell and T-cytoxic cell function, antibody response to specific antigen challenges, and reactivation of herpes viruses in response to spaceflight.

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**Cell Science and Immunology —** The cellular and molecular mechanisms by which spaceflight alters human physiology are poorly understood. Crew members experience immune system changes, muscle and bone loss, neurological alterations, and other changes in body systems. To optimally develop techniques that prevent or alleviate the deleterious effects of spaceflight, we must determine which cellular processes are altered by microgravity. JSC's Cell Science laboratories focus on the effects of microgravity on immune cell function both in vivo and in vitro. We also investigate the response of other types of cultured cells (e.g., bone cells and endothelial cells) to altered gravity environments. The laboratory is equipped for tissue culture and general biochemistry/molecular biology studies, and contains two flow cytometers, light/fluorescence microscopes, digital image systems, and a scanning electron microscope.

Results from previous studies have indicated a depression of the immune system associated with spaceflight. Observations in our laboratories have demonstrated significant alterations in circulating lymphocyte populations following spaceflight. Functional studies are being initiated to investigate the effect of these alterations on immune competence. These studies will include the examination of T- and B-cell activity, accessory cell function, and changes in immunoregulatory factors and lymphocyte trafficking. In addition, a number of investigators have shown depressed in vitro mitogen activation of lymphocytes with spaceflight. Detailed studies of gravity effects on the cell-cell interactions, signal transduction pathways, and transcriptional changes involved in lymphocyte activation are under way to delineate the mechanisms that are altered in microgravity.

These studies utilize hypergravity and simulated microgravity (clinostat) models to examine the effects of gravity at the cellular and molecular level. Understanding the role of gravity in signal transduction, transcription and translation of cellular proteins, and the cytoskeletal system will provide knowledge relevant to cellular proliferation, activation, movement, shape, adhesion, movement of organelles, and gene expression. Knowledge of gravity-induced alterations in these characteristics at a cellular level will provide a better understanding of the physiological effects observed in the various tissues and organs.

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**Biotechnology Cell Science Program —** This program uses the microgravity environment to help us understand the biological processes and to develop the technology required to overcome gravity-based limitations in cell culture and tissue engineering. We have developed bioreactors for the culture of cells using well-controlled process parameters and reduced levels of hydrodynamic shear stress, which simulates the low-gravity conditions of space to the extent possible on Earth. Bioreactors suspend cells with minimal shear forces through rotation of the cylindrical, fluid-filled culture vessel. Mammalian cells cultured in this environment aggregate and grow into three-dimensional arrays, and the cultured cells display differentiation markers similar to those found in corresponding mammalian tissue. The advantage of these bioreactor systems is that tissue-like cell arrays are suspended in a well-mixed aqueous medium that facilitates nutrient transfer and dispersion of wastes, and also makes it possible to isolate potentially novel factors. Ground-based studies using the NASA bioreactors have demonstrated that both normal and neoplastic cells and tissues recreate many of the characteristics that they display in vivo.

The Program has three major goals concerning mammalian tissues culture: (1) to accelerate the development of a three-dimensional tissue culture system using rotating-wall bioreactors, (2) to define and characterize mammalian cells and tissues that benefit from a low shear environment, and (3) to use the microgravity environment of space as necessary to surmount gravity-induced obstacles to the propagation of complex tissues.

Current research areas include effects of reduced levels of mechanical and hydrodynamic shear; the effects of spatial co-location of participating cell populations; the role of mass transport on cellular propagation and tissue assembly; the effects of culture media (e.g., growth factors) on cellular metabolism and waste accumulation; the value of low shear and spatial co-location during culturing; the development of technologies (biosensors for pH, glucose, and oxygen); new tissue culturing methods and strategies; and research into mammalian, plant, and insect culture.

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**Radiation Biophysics —** The space radiation environment primarily consists of high-energy electrons, protons, and heavy ions from solar wind and galactic cosmic rays, and high-energy particles trapped in the Van Allen Belts by the Earth's geomagnetic field. The radiation health aspects of spaceflight include unique considerations. Of critical importance from a health perspective is the radiobiological assessment of effects resulting from chronic exposure to the high-charge, high-energy (HZE) particles and solar particle events resulting from large solar flares. In addition, dosimetry must be adequate to enable accurate assessment of exposure hazards and must be responsive to a broad spectrum of radiation types and energies. Vehicle design and material selection determine the shielding afforded and must be viewed with respect to weight and volume constraints; furthermore, accurate knowledge of the ambient space-radiation environment and interaction of the radiation with the spacecraft (transport codes) are required to project expected exposures and thus enable mission-duration and mission-profile planning. Studies in progress and projected for the future include (1) biological effects of energetic protons and HZE exposures, especially carcinogenic, cytogenic, and mutagenic effects at the cellular and molecular levels; (2) cellular and molecular mechanism(s) of oncogenic cell transformation by protons and HZE exposure; (3) advanced biomarkers and biological dosimetry; (4) space radiation health physics; (5) biophysical models of HZE effects; (6) radiation protection by chemical and biological agents; and (7) possible increased biological effects resulting from simultaneous exposure to microgravity and space radiation environments.

Acceptable levels of exposure to space radiation are based on a risk-versus-gain consideration. The studies mentioned are critical to a satisfactory space-radiation health program in which exposures and long-term health risks are minimized.

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**Biotechnology and Bioprocessing —** Microgravity can be used to facilitate the separation and synthesis of medically important biological materials, as well as to enhance the formation of tissue like aggregates in specially designed bioreactors. Theoretical and experimental projects are under way to improve cell culture techniques using normal and neoplastic cell types under microgravity conditions.

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**Chronotherapeutics —** Space travelers experience ultra-short day/night cycles as the shuttle orbits the Earth every 90 minutes. Medical records and personal communications by astronauts and cosmonauts suggest that sleep disruption is a common occurrence during flights. Extended mission duration and work demands often over-extend crew schedules during flights. Reports of fatigue-related performance decrements in shift workers and other sleep-deprived groups indicate that spaceflight crews may be subjected to similar decreased operational efficiency resulting from alterations in their work-rest efficiency. JSC's pharmacology research group evaluates methods for the assessment of sleep deficits and resulting decrements in work-time alertness and performance. Laboratory activities also focus on designing and developing ground-based and in-flight countermeasure strategies for improving sleep quality and health during spaceflight.

Our goal is to generate information and identify ground-based models that can assist in the development of practical, appropriate, reliable, and effective intervention technologies and regiments that can augment health and well being to support sleep-work activity schedules of long duration flights and for a prolonged stay in the microgravity environment. Specific objectives of this investigation are to identify and characterize changes in the physiological and biochemical indices of circadian adjustments during spaceflights, and to develop and validate effective operational monitoring tools and countermeasures that will improve performance and maintain health of crew members during short and long duration missions.

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**Pharmacokinetic Research —** Spaceflight induces a number of physiological changes including fluid shifts and cardiovascular deconditioning. While some of these changes were evaluated on earlier missions, others (e.g., changes in gastrointestinal and hepatic function) have not been investigated. Availability of sensitive and flight-suitable methods of evaluation limits implementation of these studies in space. Identification and evaluation of these physiological parameters and resulting changes in the pharmacokinetics and pharmacodynamics of therapeutic agents administered during spaceflight are essential for designing and developing effective treatment regimes for the space medical operations.

Gastrointestinal and hepatic function research focuses on developing simple, noninvasive techniques to conduct these studies in space. We will use ground-based simulation models of microgravity (e.g., antiorthostatic bed rest) to evaluate and validate these techniques for their flight suitability. Using these validated, noninvasive methods, we can also evaluate changes in gastrointestinal and hepatic function during spaceflight.

Pharmacokinetics research includes (1) development of simple and noninvasive drug-monitoring methods that are flight suitable, (2) evaluation of pharmacokinetic changes of drugs during antiorthostatic bed rest, (3) pharmacodynamic implications of these changes, and (4) other changes such as protein binding and metabolism of drugs. In-flight pharmacokinetics and pharmacodynamics are characterized using methods developed in ground-based research. Research in the area of pharmaceutical development involves designing and testing noninvasive and nonparenteral drug dosage forms that are suitable for use in space. We also evaluate sustained release and intranasal dosage forms of antimotion sickness drugs.

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**Environmental Physiology/ Biophysics Research —** The physiological and biophysical interactions of environmental factors such as gas species and their partial pressures, temperature, gravity, decompression and barophysiology, and exercise are being investigated by the Environmental Physiology Laboratory. Experiments involving human subjects, primarily in the area of hypobaric barophysiology, and mathematical models of decompression are currently being pursued. The goal is to reduce the time impact of countermeasures (e.g., oxygen prebreathe) and develop monitoring equipment.

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**Pathophysiology of Decompression Sickness —** Decompression sickness (DCS) is a malady that occurs when the ambient pressure is reduced. Gas phase formation occurs and situations can progress from subclinical, to DCS, to death. Although it is generally associated with deep-sea divers, DCS can occur in aviators or astronauts during extravehicular activity (EVA).

There is evidence to suggest that the risk of DCS is reduced in microgravity environments. One possibility is a reduction in the forces which participate in stress-assisted nucleation and in vivo gas phase formation. This hypothesis is being tested in human subjects. Objective and quantitative measurements are performed using Doppler ultrasound devices. Final results of these tests will aid in formulating prebreathe procedures for EVA.

Because the current suit utilized for EVA is at a lower pressure than the space cabin, there is a risk of decompression sickness. It is helpful to monitor EVA astronauts for bubble formation, especially in real time. Problems associated with current monitoring systems include fire safety, probe placement, stability of signals, and information transmission from the suit to the monitoring station.

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**Psychological Research —** This laboratory, which functions under the auspices of the Life Sciences Research Laboratories, is chartered to study those factors which may significantly impact individual and team performance, and psychological health during space missions. The overriding goal of this laboratory is to ensure optimal performance of individual crew members and teams during space missions. Another important goal is to ensure the optimal performance of ground support personnel in their relationships with mission crews, and their interactions as a ground-based team. Many factors that affect space crews will have an impact on the ground support personnel and will require appropriate countermeasures.

Suboptimal productivity, lapses in judgment, interpersonal conflict, and other behavioral problems have been encountered on both space flights and ground-based Antarctic missions. A number of factors are presumed to account for these problems, including isolation and confinement. Current research focuses on small group dynamics and team performance in analogue mission crews, development and evaluation of methods for psychological monitoring, and cross-cultural issues related tomultinational teams.

The laboratory is equipped with several computers and software for programming, digitizing video and audio inputs, and analyzing data.

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**Workstation/Workplace Design** — Knowledge of how humans work in space is essential for planning space missions and designing equipment. Research is needed on the impact of factors which affect crew performance. Contributing factors include but are not limited to working posture requirements, workstation layout, equipment and tool design, work methods used, and task requirements. Quantifying the effect of these factors on task performance can help engineers design and modify the workplace environment for optimum crew safety and productivity. Human factors assessments were flown on STS-50 and STS-58 to evaluate the interface designs of gloveboxes. The flight experiments consisted of compiling crew comments about glovebox design prior to, during, and after the mission. We also analyzed the mission down link video to determine postural changes while working at the glovebox. The results of this experiment indicated that working at a glovebox for a long duration resulted in neck and shoulder discomfort. Some issues to be addressed in future studies include human factors requirements for the next generation glovebox design (e.g., Space Station maintenance workstation), restraint systems, and material handling in microgravity.

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**Human Modeling in Virtual Environments** — The objective of virtual environment research at the Graphics Research and Analysis Facility is to develop a computer software system for use in the design and evaluation of complex space structures. Its special features include an immersive user interface, which will allow the graphics model of a structure to be perceived as a virtual environment; and the incorporation of anthropometrically correct graphics models of humans, which can be used to investigate human factors issues such as reachability, fit, and visibility in the virtual environment. By allowing a designed structure to be seen and evaluated "from the inside" at the beginning of the design cycle, long before it is feasible to build a mockup of the structure, the system will lead to earlier recognition of potential problems and make it easier to evaluate alternate designs, resulting in considerable savings in time and funds.

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**Research on Computer Biomechanical Modeling —** One of the goals in human modeling at the Graphics Research and Analysis Facility (GRAF) is to create a task-oriented human figure model which emulates the physical characteristics of the actual human counterpart as closely as possible. Currently, GRAF's human model is used to solve problems and make predictions related to anthropometry and kinematics. Our overall goal is to extend the current strength model with a systematic and comprehensive assessment of strength for all major joints of the human, and to build a task-oriented modeling system with the astronaut characterized in terms of his/her strength/fatigue and reach limitations. The research requires that a biomechanical modeling system be built which incorporates dynamics, human strength, stamina, range of motion, workload, and fatigue. This model should extend human factors support to operational areas and emphasize the improvement of processes and products.

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**Neurosciences —** This laboratory, which functions under the auspices of the Life Sciences Research Laboratories, is engaged in a wide-ranging program of ground-based and spaceflight studies to investigate the effects of unique spaceflight environmental variables, particularly microgravity, on man's nervous system. As a result of data obtained from the Apollo, Skylab, Shuttle, and Mir missions, attention is being given to studies that attempt to elucidate those neurosensory, sensorimotor, and related physiological mechanisms underlying space-adaptation (space motion-sickness, spatial orientation, and perceptual processes) syndrome and readaptation to Earth. Included are investigations of semicircular-canal and otolith-organ interaction processes, vestibulospinal reflex responses, visual-vestibular interaction processes, vestibular-autonomic interaction processes, eye-hand coordination, and psychophysiological responses to stressful, gravitoinertial stimuli, and postural and locomotion control processes.

The primary focus is operational research directed toward developing reliable predictive techniques and effective countermeasures for space motion-sickness, "Earth sickness", and neurosensory, and sensorimotor disturbances during and after flight. Research on countermeasures centers primarily on visual and vestibular adaptation training, centrifugation, and evaluations of new pharmaceuticals for motion sickness and orthostatic intolerance. Another major focus of the laboratory is the effects of extended duration flight on visual/vestibular function, autonomic function, posture, gait, and other sensory systems. In addition, the development of countermeasures to ensure the safe return and egress of flight crews is an area of critical concern. Work is under way to develop new and improved vestibular-response measurement analysis and modeling techniques. Laboratory facilities have recently undergone considerable expansion to accommodate increased efforts to investigate etiological factors and autonomic nervous system responses underlying both motion-sickness and orthostatic tolerance. Extensive laboratory instrumentation is available for the generation and control of stimuli and the recording and analysis of a variety of responses.

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**Exercise Physiology —** One objective is to refine currently available procedures for the measurement of very small changes in bone and muscle mass. Four major physical-measurement systems are being studied: single-axis gamma-ray absorptiometry, x-ray computed tomography, nuclear magnetic resonance, and low-level radioactive counting of activated calcium. Additional indices of acute change are identified through collaborative programs in endocrinology and biochemistry.

The major emphasis is directed toward the quantification of bone mineral by computer tomography and selective rectilinear scanning techniques (os calsis and lumbar spine). Trabecular bone shows changes in mineralization much faster than cortical bone. Selective rectilinear scanning has now been developed to determine the mineral distribution in a bone section based on measurements of the transmission of gamma rays from an isotope source using a precision scanning instrument. Whole-body x-ray CT scanning of the spine to determine density is now available. One aspect of the research effort will be to miniaturize the scanning instrument and computer for use on a space station.

Magnetic resonance imaging is being used regularly to document the atrophy of the leg muscles in individuals exposed to microgravity and bed-rest simulations of microgravity. Advance-imaging techniques have been developed and are being used routinely. Measurements of changes in water content of the muscles of posture and ambulation are being made before and after periods of bed rest. High-energy phosphates are being measured in vivo and the changes in bone marrow content after bed rest are being followed. Computer enhancement of the images is under way using methods developed for Earth-observation satellites. NASA has available three different magnetic-imaging machines for use in advanced studies of muscle change.

The objectives of this research are to refine current methods of measuring biochemical factors that influence the musculoskeletal system and to correlate these factors with musculoskeletal changes during bed rest and spaceflight with and without countermeasures. Specific subtasks include (1) quantifying biomechanical loads during exercise using methods that require minimal operating space in flight, (2) automating signal acquisition and processing methods, (3) performing stress analysis on the skeleton for the exercises measured using finite element analysis, (4) measuring musculoskeletal changes during bed rest and spaceflight, (5) refining techniques to measure changes in trabecular architecture and material properties using acoustic or magnetic resonance imaging methods, and (6) correlating these changes with the exercises and stresses during exercise countermeasures.

The goal of the exercise countermeasure program is to maintain crew members' neuromuscular capability, systemic aerobic and anaerobic performance, skeletal muscle function, and bone integrity during spaceflight missions.

Laboratories supporting this research contain comprehensive facilities in the areas of biomechanics, exercise physiology, neuromuscular, and hardware development. In addition, the design and development of spaceflight exercise equipment is a fundamental aspect of the exercise countermeasure program for both the space shuttle and space station.

Operational and ground-based research is conducted. Operational research takes place during spaceflight missions, while ground-based research is performed in (1) laboratory settings, (2) underwater-thus attaining neutral buoyancy in the Neutral Buoyancy Laboratory, and (3) on board NASA's KC 135 aircraft, where short duration zero gravity is achieved by flying parabolic maneuvers.

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**Microgravity Associated Skeletal Muscle Atrophy —** Human space explorers undergo a variety of physiologic adaptations to the microgravity environment to which they are subjected during spaceflight. In both astronauts and cosmonauts, atrophy of skeletal muscle with a concomitant reduction in functional capacity when returning to the normal terrestrial gravitational environment has been documented. Reductions in calf circumference, development of negative nitrogen balance, increased urinary excretion of muscle protein-derived amino acids, decrements in strength and force-velocity relationships in selected muscles, and loss of muscle volume as verified by magnetic resonance imaging have all demonstrated muscle atrophy is a consequence of spaceflight. A variety of studies in astronauts/cosmonauts, human test subjects under conditions of simulated microgravity (bed rest and/or limb suspension), and in hypokinesia/hypodynamia animal models are in progress to elucidate the mechanism of microgravity associated muscle atrophy in order to devise, implement, and test the efficacy of countermeasures to prevent or attenuate its occurrence. The following approaches are proposed for future studies: (1) histochemical and histomorphometric evaluation of muscle biopsies from flight crew members, bed rest test subjects, or animal models; (2) quantitative image analysis of magnetic resonance images from muscles suspected of being susceptible to atrophy; (3) development and study of in vitro (tissue culture) models of muscle atrophy; (4) analysis of possible muscle atrophy markers; (5) study of structure/function relationships of muscle mitochondria and capillaries; and (6) development and testing of countermeasures. Techniques used in these studies will include muscle enzyme and lectin histochemistry, monoclonal immunohistochemistry, and morphometric analysis by digital planimetry; diagnostic medical imaging and quantitative image analysis; tissue culture and two-dimensional gel electrophoresis; spectrophotometric, spectrofluorimetric, and turbidimetric biochemical assays; in situ hybridization; and subcellular fractionation.

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**Cardiovascular Research —** For the most part, cardiovascular responses to weightlessness seem to be appropriate for the spaceflight environment. However, these responses leave astronauts ill-prepared for their return to Earth, when they have reduced circulating blood volume, reduced exercise capacity, and decreased orthostatic tolerance. Recent evidence has suggested that autonomic regulation of the cardiovascular system is a major contributor to the problems experienced on landing day. Every autonomic response that has been measured before and after flight has been different from that of preflight or landing day. The tests include Valsalva maneuvers, stand tests, baroreflex function, beat-to-beat heart rate and arterial pressure dynamics, responses to lower body negative pressure, and catecholamine responses to orthostatic stress.

We are using the above tests and others to study the mechanisms of the cardiovascular changes associated with spaceflight and to develop appropriate countermeasures. The research environments include spaceflight, parabolic flight, centrifuge facilities, and bed-rest studies. Work is performed at both JSC and nearby medical centers.

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**Cardiovascular Responses to Exercise —** Aerobic exercise capacity is decreased after bed rest or spaceflight. This decease is potentiated in the upright compared to the supine position, suggesting that at least part of the decrement is related to an orthostatic component. Research is in progress to study the mechanisms responsible for the declines in aerobic and anaerobic exercise capacities after spaceflight.

A decline in aerobic exercise capacity could result in greater fatigue during long duration work tasks such as building a space station, and could limit the ability to perform high-intensity exercise countermeasures. Research focuses on identifying an effective exercise countermeasure prescription to maintain exercise capacitythrough an efficient combination of aerobic and resistive exercises. We also study combining exercise with exposure to lower body negative pressure as a method of improving the effectiveness of aerobic exercise in maintaining muscle and bone mass, and aerobic and anaerobic capacity.

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**Space Food Development —** The Food Systems Engineering Facility supports food development activities for the Shuttle, International Space Station, and future missions. Advanced planetary missions require major efforts in food development especially in packaging and process engineering. Research areas of interest include: food development, food processing, food equipment engineering, acceptability measures for microgravity and isolation, food bioregeneration, shelf life extension up to 5 years, preservation, packaging, and food waste management.

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## SPACE SCIENCES

**Orbital Debris Hazard Assessment —** NASA Johnson Space Center has a program to better understand the character of the man-made orbital debris environment, the implications of this environment on the design and operations of spacecraft, and the development of national and international standards to minimize the future orbital debris environment.

This program consists of four major components: (1) modeling of the environment; (2) measurements of the environment; (3) hypervelocity impact testing to determine the consequences of the environment and the design of shielding; and (4) consulting with industry, other goverment agencies, and other space-faring nations for making cost-effective recommendations to minimize the hazard to future spacecraft.

Predictions of the flux resulting from the orbital debris environment are made from both source and sink models, which include spacecraft traffic models, satellite breakup models, and atmospheric drag models. We test these predictions against environmental measurements. Such measurements include the relatively large (>10 cm) objects maintained in the US Space Command catalog, intermediate sized (1 mm to 10 cm) that are sampled by ground telescopes and high-frequency ground radars, and small objects (<1 mm) that are sampled through hypervelocity impacts on recovered spacecraft surfaces. JSC obtains data using a three meter liquid mirror telescope and the Haystack radar, maintains samples from several recovered satellite surfaces, and maintains laboratories to measure the characteristics and chemistry of impact craters. To date, the measurements program has identified sources of orbital debris that were not included in the models.

The probability that a spacecraft will fail to function because of an orbital debris or meteoroid impact can be reduced with specially designed shielding. JSC maintains three hypervelocity guns, and has played a critical role in designing shields for the planned Space Station. In an effort to minimize the shielding weight of the Shuttle and Space Station, hypervelocity (velocities greater than 5 km/sec) tests are conducted on various spacecraft materials and configurations.

JSC has prepared a NASA safety standard, which includes guidelines and procedures for limiting orbital debris. We also conduct regular meetings with other US agencies and the "Inter-Agency Space Debris Coordination Committee" (with members from the US, Europe, Russia, and Japan). The purpose of these meetings is to coordinate research and reach a common consensus for the international standards of limiting orbital debris.

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**Planetary Materials Analysis and Process Simulation —** One very important approach to deciphering geologic history is through the study of trace-element abundances in rocks. Reliable interpretation of such abundance data requires knowledge of the effects of geological processes on trace-element abundances. In order to contribute to this knowledge, we are studying the partitioning of various trace elements between silicate melts and several geologically important minerals in controlled laboratory experiments. Effects of mineral and melt composition are being systematically investigated. Emphasis has been placed on minerals and liquid compositions believed to have played an important role in the geochemical evolution of the lunar crust and mantle, in petrogenesis of Martian meteorites, and in the petrogenesis of the very primitive angrite meteorites. However, studies of other compositional systems having relevance to planetary science are also encouraged. Equipment includes numerous one-atmosphere, gas-mixing furnaces capable of reaching 1,500oC internally and externally heated pressure vessels covering conditions to 10 kbars and 1,200oC, a piston-cylinder apparatus covering conditions to 30 kbars, and a controlled-atmospheric thermogravimetric-analysis system capable of reaching 1,300oC. Electron microprobe and electron microscope facilities are also available.

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**Crystallization Studies —** The dynamic crystallization of rock and mineral melts in the laboratory under controlled conditions makes it possible to study such features as rock textures, mineral zoning, element partitioning, nucleation, and the effects of co-precipitation of minerals, fractional crystallization, and differentiation as a function of crystallization conditions. By experimentally replicating the mineral assemblages and textures of natural materials in synthetic equivalents and by determining the stability of minerals, it is possible to formulate the sets of conditions appropriate for the origin and evolution of planetary crustal and meteoritic materials. Current emphasis is placed on the origin of chondrules in the nebula. The equipment available includes internally and externally heated pressure vessels covering the experimental conditions ranging up to 10 kbars and 1,200oC, one-atmosphere, gas-mixing furnaces with direct monitoring of oxygen fugacities and a piston cylinder for high-pressure experiments to 40 kbars.

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**Soil Chemistry and Mineralogy —** A research program is underway to develop synthetic, inorganic highly reactive "soils" for plant growth experiments in microgravity. One particular system, "zeoponics", is the cultivation of plants in zeolite substrates that contain essential plant-growth cations on their exchange sites and have minor amounts of mineral phases (e.g., synthetic apatite) supplying essential plant growth anions. The exchange behavior (i.e., ion-exchange selectivities, kinetics of exchange) of zeoponics systems are being examined. In addition, plant growth experiments have been conducted to determine economics of plant production in zeoponics systems compared with other plant growth systems (e.g., hydroponics).

Other projects in soil chemistry and mineralogy are encouraged, especially clay mineralogy, zeolite chemistry and mineralogy, and mineral syntheses. Several studies are underway to determine the possible mineralogy and chemistry of Martian surface materials and the mineralogy of phyllosilicates in meteorites and interplanetary dust particles. Experimental and analytical facilities include x-ray diffraction, infrared spectroscopy, electron microscopy (e.g., scanning transmission electron microscopy, scanning electron microscopy, and electron microprobe), and atomic absorption spectroscopy.

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**Experimental Trace-Element Partitioning and Petrogenesis of Extraterrestrial Igneous Rock —** One very important approach to deciphering geologic history is through the study of trace-element abundances in rocks. Reliable interpretation of such abundance data requires knowledge of the effects of geological processes on trace-element abundances. In order to contribute to this knowledge, we are studying the partitioning of various trace elements between silicate melts and several geologically important minerals in controlled laboratory experiments. Effects of mineral and melt composition are being systematically investigated. Emphasis has been placed on minerals and liquid compositions believed to have played an important role in the geochemical evolution of the lunar crust and mantle, in petrogenesis of Martian meteorites, and in the petrogenesis of the very primitive angrite meteorites. However, studies of other compositional systems having relevance to planetary science are also encouraged. Equipment includes numerous one-atmosphere, gas-mixing furnaces capable of reaching 1,500oC internally and externally heated pressure vessels covering conditions to 10 kbars and 1,200oC, a piston-cylinder apparatus covering conditions to 30 kbars, and a controlled-atmospheric thermogravimetric-analysis system capable of reaching 1,300oC. Electron microprobe and electron microscope facilities are also available.

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**Orbital Evolution Studies —** Small meteoroids in interplanetary space orbitally evolve in a different manner, and at a much faster rate, than do planets. This is because they feel the gravitational forces of the Sun and planets, and are affected by radiation pressure and by Poynting-robertson and solar wind drag. In the early solar system, they also evolve under nebular drag. Dust grains are often trapped into resonances with planets with which their orbital periods are as a ratio of integers to the planet's orbital period. Such trapped populations can form detectable heliocentric rings. Research includes numerical and theoretical orbital evolution studies-with emphasis on the former-using PC's, workstations, and a supercomputer. Application to extra-solar system dust clouds are evaluated. Analyses of spacecraft-obtained dust impact data are also conducted to characterize the distribution of current meteoroid orbital parameters.

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**Investigations of Natural and Experimental Hypervelocity Impacts —** We pursue hypervelocity meteorite impact as a geological process to learn about the accretion, differentiation, and the evolution of current, heavily cratered surfaces of planets and their moons, including the collisional evolution of small solar system objects. Our largely experimental approach uses powder propellant and light gas gun facilities to launch a variety of projectiles into geologic solids at velocities as high as 7 km/s. Postmortem analysis of these laboratory impacts may range from cratering mechanics to the shock-induced modifications of minerals and rocks. These experimental studies are partially complemented by the analysis of naturally shocked materials, field studies of terrestrial impact structures, and theoretical considerations. We are interested in the velocity distribution of crater ejecta and collisional fragmentation products, the evolution of asteroidal regoliths and meteoritic breccias, and the shock metamorphism of carbonates. Additional efforts focus on the development of aerogel as a suitable capture medium for hypervelocity projectiles in support of STARDUST, a Discovery-Class comet fly-by mission. Such capture media are also being exposed on the MIR Station to trap both natural cosmic dust and man-made orbital debris; these collectors were retrieved in September 1997 for post-flight analysis.

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**Physicochemical State of the Martian Surface —** The general objective of this continuing research program is to understand the nature and constitution of surficial material on Mars and to determine the weathering processes that evolved the surface to its current state. Specific tasks include (1) studies of geologic samples that have been weathered in terrestrial environments considered to be analogous in some important respects to those on Mars, (2) theoretical and experimental studies of the optical properties of pure and substituted iron-bearing compounds, and (3) instrument development. Emphasis is placed on multidisciplinary analyses of samples to maximize comparison with the database available for Mars from the Viking, Phobos-2, and Mars Pathfinder missions and telescopic observations. Experimental and analytical facilities include ferromagnetic resonance spectroscopy, vibrating sample magnetometer, Mössbauer spectroscopy, and ultraviolet-visible-infrared spectroscopy. Instrument development includes a backscatter Mössbauer spectrometer for planetary applications.

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**Analytical Studies of Space Weathering Effects on Lunar and Asteroid Surfaces —** A long-term program is underway to analyze and interpret many of the characteristics of lunar soils, cores, and regolith breccias. Lunar soils have formed by complex processes including impacts, solar wind implantation and radiation effects, and volcanic processes which were active in earlier lunar history. Ancient lunar soils are preserved in some regolith breccias and in some of the returned core material. A challenging research task is to decode the record in these ancient regoliths using clues from current ones, and to determine something about the meteorite flux; meteorite composition; solar wind, flare, and early volcanic activity; and general lunar evolution over the course of lunar geologic history. A major objective is to quantify the physical, chemical, and optical effects of space "weathering" on exposed lunar soils and possible asteroid regolith material (interplanetary dust particles). Research techniques include optical and scanning electron microscopy petrographic analysis; electron microprobe analysis; scanning electron microscopy studies of grain surfaces and textures; transmission electron microscopy studies of textures including radiation and shock damage; quantitative analysis of grain sizes, grain shapes, and surface features; and population studies of mineral and glass phases. Experience in petrology, scanning electron microscope analysis, transmission electron microscope analysis (including high-resolution work), image analysis, and geochemistry would be useful for this project.

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**Characterization of the Resource Potential of Lunar Regolith —** Lunar regolith contains rock, mineral, and glass grains of all sizes from cm down to submicrometer. Future robotic and human missions to the Moon will require such useful materials as oxygen extracted from oxides and silicates; solar wind implanted gases such as hydrogen, nitrogen, and carbon dioxide; and metals such as titanium, aluminum, or iron refined from rocks or soil. Research focuses on the detailed state of useful materials in unprocessed regolith. The results of this research will influence the nature of systems designed to extract the useful materials. Emphasis is placed on the state and location of implanted hydrogen, the kinetics of solid-state diffusion of these gases in lunar materials, the degree of natural reduction of oxides and silicates in lunar soils and rocks, and the amount and nature of reduced iron and other metals. Such data will add to our understanding of both the evolution of the lunar regolith and the natural processes that reduce lunar soils, which will also influence the design of chemical systems to accomplish the same thing artificially. Research techniques will include optical and analytical electron microscopes, high-resolution electromagnetic imaging, scanning electron microscopy studies of grain surfaces and textures, and studies of radiation damage as a function of depth within soil grains. We may also conduct additional laboratory experiments in controlled fugacity gas-mixing furnaces to help duplicate and understand the features found in the lunar materials. Experience in chemistry, petrology, electron microscopy, solid-state physics, experimental petrology, or optical spectroscopy would be useful for these studies.

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**Isotopic and Chemical Studies of the Evolution of Solid Objects in the Solar System** — Laboratory analyses of lunar, meteoritic, and terrestrial samples are conducted to provide isotopic, chronological, and chemical constraints for the evolution of solid objects in the solar system.

Current emphasis centers on lunar sample and meteorite analysis. Research on related terrestrial evolutionary analogs will also be considered. Facilities include clean laboratories for physical and chemical preparation of samples and two automated thermal-emission mass spectrometers for sample analysis. One of these is a multisample, seven-collector, late-generation instrument. The laboratory's lunar sample analysis program emphasizes the geochemical evolution of lunar mare basalts and highland rocks as recorded in their isotopic systematics. The meteorite analysis program applies isotopic constraints to the chronology and petrogenesis of basaltic meteorites, the formation of the solar system, and to stellar nucleosynthesis. Research which emphasizes laboratory or theoretical investigations of lunar-basalt genesis, genesis of basaltic rocks on other planetary objects, or categorization and interpretation of nucleosynthetic components in primitive meteorites is especially appropriate for our program. Research that focuses on planetary crustal development is also appropriate, as are studies that seek to unravel the cratering history of planetary surfaces or the history of meteorites in space by measuring cosmic ray-produced nuclides.

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**Noble-Gas Isotopic Abundances in Planetary Materials** — Isotopic abundance determinations of the noble-gas elements (He, Ne, Ar, Kr, and Xe) in meteorites and lunar samples furnish important information on a variety of planetary problems. Some problems recently addressed by our laboratory include (1) the isotopic composition and origin of various volatile components in the solar system, including the atmospheres of Mars and other planets, solar wind species implanted into the lunar regolith, and ancient energetic solar emissions; (2) the 39Ar-40Ar chronology of the formation and metamorphism of various meteorite types, including Martian meteorites, and of the early lunar crust; and (3) the history of collisional breakup events among meteorite parent bodies and the ages of lunar surface features using noble gases produced by energetic cosmic ray protons and by 39Ar-40Ar dating. Most types of isotopic measurements of noble gases are possible, including those on irradiated samples. Available equipment includes two high-sensitivity noble gas mass spectrometers with computer control, low-blank induction-heated furnaces equipped with thermocouples, an infrared laser equipped with a focusing and imaging system, a gas calibration system, and low-blank vacuum systems.

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**Volatiles in Extraterrestrial and Terrestrial Materials —** Studies of the abundances, distributions, and isotopic compositions of volatiles in lunar samples, meteorites, interplanetary dust particles, and terrestrial samples provide important information of the past thermal conditions and gaseous environments under which they were formed and have undergone subsequent modifications. Studies of the volatile elements (i.e., H, C, O, N, and S), abundances, and isotopic compositions in extraterrestrial materials help us understand the evolution of volatiles on other bodies in our solar system. Recent investigations have concentrated on the study of meteorites from Mars. Our work has shown the presence of possible biogenic activity within one of the oldest Martian meteorites. Research on the isotopic composition of oxygen (i.e., three isotopes) within components in the Martian meteorites reveals distinct oxygen reservoirs. Carbon isotopic compositions of carbon-bearing components within the Martian meteorites vary by over 100 per mil, suggesting a record of extreme carbon fractionation on Mars. We take isotopic measurements of the volatile elements within samples after we characterize materials with microscopic observations. These combined studies help us decode the unusual record of biogenic activity recorded within the Martian meteorite.

Investigations use the latest analytical equipment, including two stable isotope mass spectrometers, and laser microprobes interfaced to either mass spectrometers or gas chromatographs/computer systems. Other examples consist of (1) microfluorination-laser extraction techniques for the measurement of three isotopes of oxygen within silicate systems; (2) microthermometry for the study of fluid inclusions; and (3) analytical instrumentation to determine the identity of the volatiles released during heating and/or crushing and laser extraction, and to determine abundances, temperature-release ranges, isotopic compositions, and sequence of release. Analytical facilities are also available for the measurements of abundances, distributions, and isotopic compositions of a variety of terrestrial and extraterrestrial materials.

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**Space-Radiation Environment —** Space-radiation environment is a significant consideration in planning any long-duration mission both in low-Earth orbit and in interplanetary space. To maintain our ability to assess the environment and to minimize the risk to humans in space, an active program entails computer modeling of radiation received by the human body and careful measurements of the radiation environment both outside and inside the space shuttle. Research concerns advanced concepts of dosimetry, including identification of the elemental composition, energy, and direction of incident radiation, as well as real-time calculations and display of radiobiological effectiveness.

This currently involves the design and construction of a solid-state charged particle telescope and acquisition of data on the inner radiation belt and galactic cosmic rays (GCR) through its operation on Shuttle flights and Mir flights. Other activities include improvements of GCR models and inner belt models to account for variations caused by the 22-year solar cycle.

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**Geochemistry of Lunar Rocks, Achondrites, and Terrestrial Analogs —** Lunar highland igneous and metamorphic rocks are products of early lunar differentiation which have been broken and reheated by meteorite impact. Achondritic meteorites are fragments resulting from differentiation and impact on smaller, usually asteroidal parent bodies. Some achondrites are igeneous meteorites blasted off the surface of Mars. Terrestrial igneous rocks, both volcanic and plutonic, result from differentiation on the much larger and more complex planet Earth. Studies of the four types of materials may lead to a broader understanding of planetary differentiation. Major and trace-element analyses by neutron activation are coupled with petrologic studies of the planetary fragments and experimental studies of analogs in order to look through these impact processes to the precursor igneous rocks and evaluate planetary differentiation. Studies of terrestrial analogs to lunar and meteoritic igneous rocks are valuable in constraining the processes of igneous differentiation.

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**Mineralogy of Fine-Grained Extraterrestrial Materials —** The early history of the solar system is being explored through detailed characterization of the minerals and noncrystalline phases composing primitive extraterrestrial materials. As these materials are typically very fine grained, this research is being performed principally by analytical electron microscopy, high-resolution transmission electron microscopy, and x-ray microdiffraction, as complemented by standard petrographic and electron-beam techniques. We are currently examining carbonaceous chondrites, as well as interplanetary dust particles (IDP) collected from the stratosphere and from Greenland and Antarctic Ice. Of particular interest are IDPs with refractory mineralogies, which potentially contain very primitive nebula condensates and/or presolar materials and the record of low-temperature planetary alteration processes, as revealed by the paragenesis of the matrix phases within carbonaceous chondrites. We are also developing particle collectors for the Stardust Discovery Mission to Comet Wilde Z and are characterizing collection surfaces flown on the Long Duration Exposure Facility, Eureca, and Mir.

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**Experimental Investigations of Planetary Processes —** Experiments delineating the geochemical behaviors of chemical elements during planetary processes are important for understanding the elemental abundance patterns that are observed in planetary materials. Specifically, geochemical behaviors of elements change with temperature (T), pressure (P), oxygen fugacity (f02), and bulk chemical composition of the system (SCi). Laboratory experiments are performed to better understand the detailed geochemical behaviors of trace elements in planetary processes such as core formation and basalt genesis. The results of these studies are then used to understand the origin of meteorites, the Earth, and the Moon. Because the conditions that pertained during laboratory experiments are seldom identical to those occurring in nature, it is also important to have means of extrapolating laboratory results to different (P, T, f02, SCi) conditions. Thus, our research objectives are (1) to determine the geochemical behaviors of elements in the laboratory, (2) to use these experiments and standard thermodynamic techniques to extrapolate from the laboratory to natural systems, and (3) to use the extrapolated experimental data to constrain the nature of planetary processes.

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**Surface Compositional Studies of Planets and Asteroids —** The surface mineralogical composition of solar-system bodies has been studied by observing the reflected sunlight in the visible- and near-infrared (IR) spectral ranges and in the thermal-IR emissions of longer wavelengths. Changes in the surface material's mineralogic composition appear as variations in the reflectance spectrum. Research in this area will concentrate on studying the surface compositions of the low albedo asteroids. Thermal-IR and ultraviolet-visible telescopic observational data will also be acquired, extending the studies to different spectral regions. Future research will include the study of weak absorption features attributed to Fe2+ - Fe3+ charge transfers in iron oxides that are present in phyllosilicates, as seen in the narrowband reflectance spectra of primitive asteroids. Planetary surfaces research is supported by an image-processing system, ground-based telescopic data, and imagery obtained from unmanned space probes.

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**Planetary Impact Processes —** Impact is the only major geological process common to all of the solid bodies of the Solar System. As a result of this single pervasive mechanism, craters and regoliths are formed on the planetary-scale objects, asteroids and satellites are disrupted, and particles are supplied to the interplanetary dust complex. Many aspects of impact cratering and collisional disruption fall within the purview of the Experimental Impact Laboratory.

Although such experiments can be performed with either of the other two guns in the laboratory, cratering and collisional-disruption experiments are primarily conducted with a vertical gun. Projectiles of various compositions ranging between 3 and 20 mm in diameter can be launched at velocities of hundreds of meters to nearly 3 km/s. In addition, target materials can be varied as dictated by experimental objectives; a refrigerated target chamber permits the use of ice and other low-temperature targets.

Recent investigations have included disruption of various rock and ice targets, the physical and chemical evolution of "experimental regoliths", measurement of ejection velocities, and the chemistry and petrography of agglutinate-like particles created during the regolith-evolution experiments. Theoretical and observational studies of these processes are encouraged.

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**Trace Element Analyses of Submicrogram Samples by Ultrahigh Sensitivity Instrumental Neutron Activation Analysis —** Many problems in trace element geochemistry have not yet been pursued because available analytical techniques cannot provide sufficiently precise data on small enough samples. We have extended instrumental neutron activation analysis techniques to allow precise analysis of small particles. Overall increases in sensitivity are approximately a factor of a million, so that samples weighing from a few nanograms to a few micrograms can be analyzed for up to 25 elements. The techniques involve irradiations in a high-flux nuclear reactor, followed by gamma-ray counting that utilizes large, low-background germanium detectors in the Radiation Counting Laboratory-an excellent, low-background, underground counting facility. In addition, techniques are continually being improved to interpret the trace element abundance data. These techniques depend on analyzing enough samples to evaluate grain-to-grain heterogeneity, and on understanding the detailed mineralogy of the samples. Because the analyses are nondestructive, subsequent mineralogical analysis can be done by electron microscopy. Alternatively, use of a new micro-coring device allows us to remove samples from previously studied petrographic thin sections. Samples analyzed have been mainly interplanetary dust particles (commonly called "cosmic dust") collected by high-flying aircraft, and various clasts and minerals in a variety of lunar and meteoritic breccias.

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**Space Radiation and Biological Systems —** Applicants should be interested in performing theoretical modeling of the effects of space radiation on biological systems. Emphasis is placed on the relationship of the track structure of heavy particles (protons, alpha particles, and heavy ions) to DNA damage and resulting biological responses such as mutation and signal transduction. One of our goals is to develop theoretical models that can describe molecular biology experiments performed to study heavy particle effects. Nuclear reactions in spacecraft shielding and tissue modify the composition of the primary radiation fields including the production of new particle types. The importance of nuclear reactions in risk assessment include the role of shielding material type on reaction rates and the high-energy deposition events that would occur in tissue near reaction sites. An additional goal is to develop biological response models that describe nuclear reactions, track structure, and molecular interactions that will be able to guide the design of optimal shielding materials for radiation protection. Interested applicants should have a background in radiation physics and track structure models, as well as a basic knowledge of molecular biology.

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**Remote Sensing of Earth's Biomes —** The imagery from Space Shuttle cameras and other unmanned satellites is used to model the ecological changes occurring in the Earth's biota. Current efforts include mapping and monitoring biomass burning in the global tropics to model the contributions of this phenomena to greenhouse gases. Other episodic events such as Kuwaiti oil fires are also analyzed to determine the dynamic nature of these biomass-atmosphere interactions. Emphasis is placed on the role of remote sensing from the Space Shuttle and Space Station sensors for global change research.

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**Earth Observations Database —** The NASA Space Shuttle Earth Observations Database is a valuable source of data for research of Earth’s recent environmental history, and thus for assessment of the human impact on global Earth processes. This data source, although having the longest length on record of any space derived global change database, has not been fully exploited by scientists studying the global changes.

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## MISSION OPERATIONS

**Advanced Operations Technologies —** Self-sustained long duration human operations in deep space and support of multiple-vehicle operations will require a revolution in ground and on-board operational techniques. This revolution has to be supported by the development of new innovative/enabling operational tools to be both cost effective and safe. Focus will be placed on vehicle and ground systems technology developments which will require minimal human operational intervention in use. This will drive operations costs down and should improve safety. Operational support capabilities based on cutting edge information systems technologies will be required to enable the reduction in real-time round the clock ground support and training (operations costs) and/or reduce flight crew required attention to maintenance, monitoring, training, and planning (more time for science). Enabling tools are envisioned to be those which utilize advanced computational techniques such as agent-based systems, natural language programming, automatic code generation, validation and verification, and advanced simulation and modeling. Automation tools based on intelligent systems such as expert systems, intelligent search, adaptive reasoning, model- and case- based reasoning, intelligent estimation and diagnostics, need to be develop for applications such as autonomous navigation and flight dynamics tools, automated planning and scheduling, and intelligent operations assistants for automated fault detection/recovery/control. Research is needed on advanced human-machine interfaces such as virtual modeling and visualization, data immersion, tele-presence, video teleconferencing technologies, voice recognition/synthetic speech applications to command and control. Research is also needed to enable development of advanced systems for mission data handling such as video compression technologies, automated link management systems, automated data collection/reduction/distribution agents, high capacity/secure networks for data, voice and video.

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**Command and Control Systems Networks —** Research opportunities exist for the following areas of interest: Utilization of high speed switching networks, such as ATM, in support of command and control systems for multiple critical space mission operations. Routing and processing of multiple data types (voice, video, data) and performing commanding in real-time critical conditions.

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**Command and Control Systems Real-time Vehicle Processing** — Research opportunities exist for the following areas of interest: Utilization of commercial off the shelf software (Windows NT) in performing real-time analysis of data (1000 plus samples per second) in support of mission critical operations.

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**Integrated Space Vehicle and Ground System Network** — Research opportunities exist for the following areas of interest: Developing methodologies and systems that allow for wide area communications, even across satellites and deep space, that look transparent to the end user. This research would have to take into account signal degradation, latency, and loss of signal while maintaining a consistent and reliable information and data exchange for critical mission support.

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**Virtual Reality interface for Space Exploration Missions** — Research opportunities exist for the following areas of interest: Developing Virtual reality interfaces into the command and control systems of exploration vehicles for command, control and status of mission systems. This research would look at alternate methods of crew interaction with the exploration vehicles that will not require them to be tethered to a computer display. Research opportunities also exist for Virtual communication between the exploration crew and the community on earth.

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**Data Archive for Space Exploration Missions** — Research opportunities exist for the following areas of interest: Developing alternate archiving methodologies and systems to accommodate archive of data on the order of quintillion bytes. The methodologies should include information storage instead of data storage; integrated voice, video and data storage and retrieval; distributed and integrated interplanetary storage.

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**Control Theory Application to Management Principles —** Apply control loop theory and methods (typically used in mechanical engineering and aerospace engineering applications) to quantify management principles. For example, investigate the hypothesis that if projects are attempted with too much lag between the time a change is needed (e.g. purchase hardware/software or change personnel) and the time that the change is made, the system (i.e. the project) will go unstable and “crash” -- just like a control loop for an aircraft will go unstable if too much lag is introduced in the system.

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Operation Technology

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**Advanced Training Technologies —** Proposals are sought that advance the state of the art in technologies that support training of NASA astronauts and ground based personnel, including simulations. NASA has a special interest in technologies that will reduce the cost and/or enhance the effectiveness of training and training development. In addition to training, proposals are also sought which could lead to the development of intelligent applications for retrieval, management and understanding of text and other Internet and/or intranet information. Proposals are strongly encouraged that demonstrate a high probability of dual use in industry and/or education for the developed technologies.

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## INTERNATIONAL SPACE STATION

**Acoustic Emission Control Systems —** The research area includes studies of practical, cost-effective methods for reducing the acoustic noise from standard fans, pumps, locking mechanisms, etc., which are commonly found on spacecraft, such as the International Space Station. Research will require a review of acoustic emission sources and existing damping methods, as well as the identification of new damping materials and the generation of new methods for controlling spacecraft acoustic noise environments.

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**Plasma Environment - Charged Spacecraft - Contamination Flow Analysis —** The research area is related to “Two Phase Flow” and includes an extension of that study to analyze the interaction of spacecraft electrical charging, the ambient and induced plasma environment, and the flow of contaminants and their deposition on spacecraft surfaces. Research will require theoretical and computer analysis, as well as planning of orbital experiments for validating the analysis on real spacecraft, such as the International Space Station.

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**Space Station Free-Flying Experimental Module Analysis & Design —** The research area is related to the need for a cost-effective and extremely gravity-free orbital research environment – nano-g rather than micro-g. The nano-g free-flyer will leave and return to the International Space Station. One approach is to utilize the proven free-flying capabilities of the Russian Soyuz spacecraft, although other approaches are welcome. Research will require engineering analysis, as well as planning of orbital experiments for validating the analysis on real spacecraft, such as the International Space Station.

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**Safety, Reliability and Quality Assurance**

**Risk Management —** Opportunities exist for research in areas related to reliability and safety of space vehicles. Multivariate models, such as logistic regression and proportional hazards models, and system reliability models that make use of dependencies between component failure events are specific topics of interest in statistical reliability. Probabilistic fatigue and other physics of failure modeling which may include simulation studies using finite element models are safety topics of interest.

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**Structural and Mechanical Reliability —** JSC is interested in studying structural and mechanical reliability from the physics of failure approach, which addresses the physical causes of failure and estimates the probability of their occurrence. Specific interest is in the areas of random processes and random fields as applied to the development of a capability in stochastic finite element analysis, and in applications of stochastic finite element methods to reliability based optimization, fatigue, and fracture mechanics analysis.

Another structural reliability interest area is in code calibration and the specification of safety factors and design standards. In particular, research is needed to quantify variability in load processes, material properties, and manufactured quality in aerospace applications.

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**Micro/Nano Technologies Reliability & Quality Control —** To develop an evaluation capability required to achieve the confidence levels necessary to assure successful verification and validation process of micro/nano technologies particularly the MEMS (MicroElectroMechanical Systems). Understanding of failure mechanisms and new quantitative analysis approaches need to be developed for evaluating the reliability and maintainability of these micro scaled devices and sensors.

Examples of the types of new approaches required for the reliability and quality assurance include quantifying the behavior of materials used for the micro/nano scaled devices, determining the failure mechanisms and the probability of failure of these devices while taking into account the added redundancy that is possible because of the low weight, low power, and inexpensive nature of these devices.

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**Nanostructured Materials Quality Assurance —** Innovative methods of investigating nanostructured materials are requested. With the recent developments being made in developing materials systems based on nanometer size features (particles, grain-size, physical phenomenon, including fullerenes and nanotubes, etc.) a need exists to acquire new methods of investigating this new class of materials as to properties, reliability, and process quality assurance. Diagnostic methods of isolating nanophase conditions are sought, particularly which can be integrated into manufacturing and service conditions for routine assessments.

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**Nanotube Safety Study —** Biological and toxicity study on the effects of carbon nanotubes on humans. Proposals are sought that study the effects of nanotube exposure to humans from handling and inhalation that might be the result of airborne particles and other direct contact methods.

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**Wireless System Safety Risk and Risk Mitigation —** Wireless system is used for data transmissions from critical sensors such as strain gauges, thermometers, and accelerometers on spacecraft. Risk and risk mitigation of the wireless system become more important as the design for long duration deep space flights become more complicated. It is urgently needed to investigate the following risks and risk mitigation of wireless systems on board a spacecraft: noise from space; interference from other wireless system such as communication systems to and from ground; interference from transceiver nodes in the same WS; in case of accidental meteoroid hits; failure due to changes in the component characteristics such as receiver sensitivity change and frequency stability change in the synthesizer; critical data loss due to the malfunction of the WS components.

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**MEMS COTS Parts Qualification and Certification Criteria —** This task is (1) to establish Qualification and Certification criteria to be used in assisting spacecraft developers in the selection of radiation tolerant microelectronics parts for human mission insertion, (2) to define the resolution of MEMS radiation hardness assurance problems, and (3) to develop MEMS COTS parts qualification and certification criteria for the future spacecraft system design readiness reviews.

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**MEMS Device Pre/Post Processing Characterization —** In order to understand the problems involving a variety of applied loading conditions of a MEMS device, including externally applied static forces, pressures and temperatures, the inner working of the MEMS devices must be fully characterized to predict temperature, stresses, and dynamic response and possible failure mechanisms. Finite Element Analyses in various cases have been effectively applied to assist in the design reliability.

This task will perform various Finite Element Analyses such as heat transfer analysis, thermal stress analysis, thermal fatigue stress analysis, static analysis, and model analysis of the selected device for design reliability characterization.

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**Develop Packaging Process Guidelines for MEMS and ASIM —** Since MEMS can interact with the environment through mechanical and fluid forces, the traditional EEE parts packaging process can no longer assure the desired quality. Packaging should include integration of MEMS with electronics on a single substrate, interconnection of circuits in a multichip module, interfaces with the macroscopic parts, and meet space environment requirements.

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**Develop Spacecraft System Interface Requirements for Micro and Macro Hybrid Systems —** To develop interface requirements for hybrid systems which integrate micro scaled devices such as MEMS (MicroElectroMechanical System) and ASIM (Application Specific Integrated Micro-instruments) to the existing traditional macro scaled spacecraft systems. Interface requirements include: electrical, optical, thermal, fluid, and mechanical specifications for interconnects and packaging.

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**MEMS COTS and ASIM Devices System Insertion Risk Assessment —** This task identifies existing candidates for MEMS (MicroElectroMechanical System) and ASIM (Application Specific Integrated Micro-instruments) devices insertion to the spacecraft for either upgrade or replacement to the existing macro scaled parts. The candidates to be replaced by MEMS are the devices which are heavy, in large size, and consume high power.  This task will study the system insertion architecture of selected system(s) to identify integration interface risks of the hybrid system (contains both micro and macro devices).  Risk mitigation methods will also be identified.

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# John F. Kennedy Space Center

## MISSION

The John F. Kennedy Space Center (KSC), located on Merritt Island, Florida, is NASA's primary launch site. The Center is responsible for assuring that sound, safe, and efficient practices and processes are in place for launch site processing. KSC personnel contribute operational expertise to the design and development of new payloads and launch vehicles and partners with a wide range of entities to develop new technologies for future space initiatives. The center's focus is shifting from primarily operations to research and development, and will cumulate in transition to a Spaceport Technology Center. The Spaceport Technology Center pillars are built around our Center of Excellence recognition in Launch and Launch Vehicle Processing Systems, Payload and Payload Carrier Processing Systems and Landing and Recovery Systems. It is within these broad areas that we focus our research effort on the development initiatives listed below. For more information on KSC, check our home page at http://www.ksc.nasa.gov/. Additional information concerning the following opportunities may be obtained from the university programs manager, preferably via email.

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### SPACEPORT TECHNOLOGY DEVELOPMENT INITIATIVES

**Command, Control, and Monitor Systems**
Key technology areas include:
- Integrated Vehicle Health Management
- Predictive Health and Reliability
- Autonomous Launch and Surface Operations

Current projects include the next generation launch processing computer system called Checkout Launch and Control System (CLCS) and Space Shuttle upgrades and Future X-vehicle integrated vehicle health management (IVHM).

**Range Systems**
Key technology areas include:
- Weather Prediction and Forecasting
- Range Capacity Improvements (launch decision support modeling)

- Digital Command Receiver Decoder

Current projects include the passive coherent locator and autonomous flight safety systems

**Fluids and Fluid Systems**
Key technology areas include:

- Automated Umbilical Development
- Cryogenics Test-bed
- Cryogenics/Super Insulation

Current projects include flame trench hydrogen entrapment and disposal testing, Mars in-situ propellant production (ISPP) technologies, Mars atmospheric CO2 acquisition and storage, Mars ISPP O2 production technologies, liquid O2 quantity sensor, and advanced closed circuit breathing apparatus technology.

**Materials Evaluation**
Key technologies include:

- Electrostatic Discharge Characterization
- Mars Environment Simulation
- Corrosion
- Environmentally Compliant Coatings
- Characterization of Physical Properties

Current projects include halon alternatives, polymer characterization, study of electrostatic charging and discharging in simulated Mars environment and development of liquid applied coatings for protection of steel in concrete.

**Process Engineering**
Key technologies include:

- Process Modeling and Analysis
- Management Support Systems (KSC Scorecard Metrics)
- Human Factors Engineering
- Work Methods and Measurement (Advanced work instruction system)

Current projects include Spaceport systems processing model, root cause analysis and remote access, internet-based data acquisition system.

In addition to the Spaceport Technology Development Initiatives listed above, KSC is focusing on some cross-cutting technologies listed below:

**Logistics** — Investigation of corrosion preventative coatings, accelerated corrosion testing techniques, thermal protective coatings, high pressure oxygen compatibility of materials, cleaning of materials, life cycle analysis, and shuttle processing improvements of ground support systems.

**Environmental Engineering and Management** — Research on effects on Kennedy Space Center operations on barrier island ecosystems. Studies also include monitoring and assessment of habitat management programs on vegetation, federally-listed threatened and endangered species, and other protected species found on Kennedy Space Center's wildlife refuge. Studies on use of geographic information systems (GIS) as decision support for environmental monitoring, remediation, pollution prevention and management.

**Safety and Mission Assurance** — Perform research in the identification and control of hazards, probabilistic risk assessment, fault tree analysis and applications, interactive hazard information tracking and closure systems, reliability engineering, personal protective devices and world class surveillance.

**Workforce Development and Management Systems** — Perform research on project resource management systems, customer focus systems, and critical skills analysis.

# NASA Langley Research Center

## MISSION

The mission of the NASA Langley Research Center is to increase the knowledge and capability of the United States in a full range of aeronautics disciplines and in selected space disciplines. The following information provides, by Competency an overview of the current disciplines in the Langley program. Specific research activities associated with each discipline are also included.

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**Aerospace Systems, Concepts, and Analysis Competency —** The Aerospace Systems, Concepts, and Analysis (ASCA) Competency purpose is to develop and deliver advanced concepts and systems analyses results that enable program offices to meet program objectives and that enable the Agency to develop future aerospace technologies. Areas of expertise include aerospace advanced concepts development, aerospace enterprise goal achievement and benefits assessment, and independent assessment of aerospace concepts. Areas of research include advanced aerospace vehicle concepts, multidisciplinary analysis methods and tools, high performance computational test beds, independent assessments, planetary entry systems, planetary aircraft concepts, and International Space Station concepts.

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**Vehicle Analysis and Planetary Exploration Branch —** The Vehicle Analysis Branch enhances the Aerospace Systems, Concepts and Analysis Core Competency effort through developing advanced aerospace concepts to meet Agency and National space transportation goals. VAB conducts conceptual analysis of launch vehicle concepts, hypersonic airbreathing systems, in-space transportation systems, and planetary entry systems. It provides technical expertise in the following areas: systems analyses of new and existing aerospace vehicle concepts to improve systems performance, reliability, safety and reduce cost; technology assessments and evaluations to aid in hypersonic and space transportation technology program planning and implementation; aerodynamics and performance database development for near-term flight systems; assessments and improvements to planetary entry flight systems and human exploration of space development activities. VAB provides systems analyses and independent evaluations to the NASA Independent Program Assessment Office and maintains and develops analytical expertise and analytical tools to support the systems analyses activities.

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Spacecraft and Sensors Branch

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**Spacecraft and Sensors Branch (SSB) —** The Spacecraft and Sensors Branch (SSB) enhances the ASCA Competency effort by conducting Phase A designs of spacecraft, instruments and experiments. The Branch performs analysis of mission concepts for the International Space Station (ISS), human space exploration, as well as space missions that do not require crew participation. SSB provides technical expertise in the following areas: definition and conduct of engineering studies and technology trades, analysis of spacecraft subsystem performance and interfaces; assessment of critical issues; independent evaluation of flight and ground systems performance; and system requirements analysis. The Branch develops and maintains the LaRC Collaborative Engineering Center (CEC) and provides expertise relative to the development of the NASA Intelligent Synthesis Environment (ISE) program. SSB develops electro-optical/microwave instrument concepts consistent with mission requirements. SSB conducts research on the utilization of GPS reflective signals to determine sea/surface state as well as land surface features. SSB conducts analytical studies of space experiments and accommodations for these experiments.

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Systems Analysis Branch

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**Systems Analysis Branch (SAB) —** The Systems Analysis Branch (SAB) conducts multidisciplinary studies and analyses of advanced vehicles and the integrated air traffic system. The goals of the Branch are:

- Identify high-potential future concepts
- Provide analyses in support of major research programs and program planning
- Provide assessment of Aero-Space Technology Enterprise Three-Pillar Goals
- Develop and disseminate advanced system analysis methods and databases

Disciplinary expertise for conceptual studies includes the following areas:
- Aerodynamics/stability and control
- Propulsion and noise
- Performance and sizing
- Configuration integration and subsystems
- Weights/structures and aeroelastic analysis
- Aviation safety
- Cost/risk/airspace system and global benefits

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Advanced Aircraft Branch

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**Advanced Aircraft Branch (AAB) —** Advanced Aircraft Branch (AAB) is responsible for theoretical, experimental, and overall systems studies directed toward advancing the state of the art for survivability of advanced military aircraft. AAB functions as an in-house conceptual design group which integrates the aerodynamic, propulsion, structural, and survivability aspects of high-performance military vehicles. The Branch conducts additional contracted studies to support in-house conceptual design work and serves as an interface and stimulus between basic research and practical applications. Performs systems analysis studies of vehicle concepts, specific aircraft, and impact of individual technologies. AAB identifies new research program thrusts and defines system-level benefits and advocacy material.

AAB provides systems analysis support to agency programs by close interaction with Langley Vehicle Thrust Managers, other groups including the Core Competency Groups, NASA Headquarters and other Centers and agencies. AAB assesses progress toward specific program goals with appropriate metrics, identifies potential application of new technology, and encourages interaction between focus groups across competencies at Langley.

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**Multidisciplinary Optimization Branch —** The Multidisciplinary Optimization Branch conducts basic research in Multidisciplinary Design Optimization (MDO) methods and participates in MDO applications with other NASA researchers and the U.S. industry.

The focus is the development, demonstration, and validation of computational MDO techniques and tools for the design and optimization of aerospace vehicles throughout their flight envelope. Specific areas of methods research and applications include: optimization algorithms, system decomposition and mathematical formulations of MDO; computational environments and frameworks for MDO; design-oriented analysis at the system level; parametric geometry modeling and computational gridding; and the extension of MDO to embrace the entire lifecycle of engineering products. A major goal of this effort is the timely transfer of validated technology to the U.S. industry and to NASA researchers.

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**Computational AeroSciences Team —** The Computational AeroSciences Team manages the Langley High Performance Computing and Communications Program (HPCCP), which includes activity in the Computational AeroSciences (CAS) Project and Learning Technologies Project (LTP). The main CAS focus at Langley is the development of computational tools, visualization tools, databases, user interfaces, and system software to facilitate the multidisciplinary design and optimization of aerospace systems. The Learning Technologies Project increases public access to scientific databases, develops new applications and pilot programs for using science data, and creates new curriculum products and tools for K-14 education.

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Computational AeroSciences Project

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Learning Technologies Project

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**Airborn Systems Competency —** This Competency conducts focused and basic research and technology development programs in flight mechanics, guidance, navigation, control, crew systems, and operating procedures for aircraft and spacecraft. It also develops analytical methods, experimentally evaluates methods and concepts, and serves as the Research and Technology focal point for flight and piloted simulation testing. Opportunities for research exist within areas of electronic and optical technologies for aircraft- and spacecraft-borne systems. Research is aimed at information acquisition, processing, and systems integration for mission- and life-critical aerospace applications. Responsible for conduct of all NASA flight operations and implementation of real-time flight simulations for the Langley Research Center. Assist in the formulation of flight and simulation programs to safely extract research information from flight and/or simulator experiments. Plan, fabricate, and install aircraft experimental modifications and instrumentation. Develop discrete mathematical models of vehicles and their subsystems for pilot in the loop simulations. Provide advocacy and consultation for a robust aviation safety program. Maintain, modify, repair, and ensure airworthiness of all aircraft assigned to the Center. Develop special flight and simulator research techniques to fit the needs of specific aeronautical, electronic, structural, and space research programs. Provide experienced personnel to serve as test aircrews in aeronautical and space simulator and other human factor studies.

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## STRUCTURES AND MATERIALS COMPETENCY

The Structures and Materials Competency conducts research on advanced materials and nondestructive evaluation (NDE) technologies for aircraft and spacecraft structures. Materials research includes development of high-performance polymers, light alloys and composites, and the processing and manufacturing technologies required to improve performance and reduce weight and cost of aerospace structures. Service life testing is performed to establish durability of these materials under simulated aircraft and spacecraft service conditions. Analyses and modeling are performed to predict structural integrity and develop a fundamental understanding of failure mechanisms.

Nondestructive evaluation techniques and methodologies are developed to inspect aircraft and space launch vehicle structures.

The Competency also conducts a wide variety of analytical and experimental research aimed towards the development of more efficient structures for aircraft and space vehicles. Research studies focusing on analytical methods for improving structural analysis and design are developed and validated by laboratory experiments. New structural concepts for both metal and composite structures are also developed and evaluated through laboratory testing. Additional research is conducted in integrating advanced structural and active-control concepts to enhance structural performance. Studies of landing and impact dynamics focus on increasing safety during ground operations and crash impact. Research in the aeroelasticity area ranges from unsteady aerodynamics for current and future aircraft and space vehicles to wind tunnel tests of flutter models.

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## AERODYNAMICS, AEROTHERMODYNAMICS AND ACOUSTICS COMPETENCY

Opportunities for research exist in the areas of theoretical, computational, and experimental investigations in the areas of aerodynamics for advanced transport and military aircraft; aerothermodynamics for aerospace vehicles and planetary entry systems; hypersonic airbreathing propulsion for hypersonic aircraft and launch vehicles; and fluid mechanics and acoustics for the design of modern aircraft, rotorcraft, missiles, and spacecraft across the speed range. Particular areas of emphasis include configuration aerodynamics; high-lift aerodynamics; component integration; Reynolds number effects; hypersonic aerodynamics and aeroheating; scramjet engine flowpath research; fluid flow physics; high temperature gas dynamics; boundary-layer transition and turbulence; laminar flow control; flow physics; vortical flow control across speed range; aircraft, rotorcraft, and spacecraft noise and its effects on structural integrity, vehicles performance, and passenger and community acceptance; engineering support; advanced concept development; and calibration. Maintains and ensures effective utilization of all Competency wind tunnel facilities. Conducts research and development in the areas of models, instrumentation, data acquisition systems, and test techniques for ground-based labs and wind tunnels to continually enhance wind tunnel productivity, data quality, and customer satisfaction.

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Research Support (Gas, Fluids, Acoustics)

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## SYSTEMS ENGINEERING COMPETENCY

The Systems Engineering Competency provides systems engineering, fabrication, facility maintenance, and information services that enable Agency programs/projects and Center competencies to meet commitments. The process for systems engineering includes deriving systems requirements from program/project goals, creating design concepts, performing design studies, selecting/implementing design, verifying design, assessing design, integrating systems/testing/activating systems, and maintaining systems.

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**Flight Systems Technology —** The organizations in this technology area pioneer and provide technology, systems, and services in the areas of flight instrumentation, engineering design, and fabrication of flight hardware and research test articles and equipment to sustain Langley's continued research preeminence. The following items represent active research disciplines.

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**William E. Miller**
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Semiconductor Detector Technology

**James C. Barnes**
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Solid-State Laser Materials

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Uv & IR Detector Technology

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Analog Digital Processing

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a.e.motley@larc.nasa.gov
Mechanical Systems Engineering

**William W. Fernald**
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Mechanical Systems Development

**Dr. William S. Lassiter**
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Thermal, Fluids, and Structural Analysis

**Advanced Computational Capability —** This activity includes computer-generated scientific visualization, image processing, grid generation, numerical techniques for high-performance scientific computers, computer networking technology, user interface development, and mass storage techniques.

**Dr. Jules J. Lambiotte**
(757) 864-5792
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Scientific Visualization
Image Processing
Grid Generation
Numerical Techniques for High-Performance Scientific Computers

**Kennie H. Jones**
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Data Management
User Interface Development

**Joseph D. Nolan**
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Computer Network Technology

**Dr. Frank C. Thames**
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Scalable Computing Architectures

**Juliet Z. Pao**
(757) 864-7328
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Mass Storage Techniques

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**Automated Information Security —** This activity develops risk analysis methodology for a distributed systems environment, computer security applications, and system interrogation techniques.

**Geoff Tennille**
(757) 864-5786
g.m.tennille@larc.nasa.gov
Automated Information Security

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**Information Management Systems** — This organization handles Scientific and Technical Information Management Systems (IMS) development, integration, and operation. IMS includes implementing an information architecture through standards development, technology assessments and assimilation, data modeling, distributed relational database management systems, and decision support systems using mainframe, client/server, and personal computing platforms.

**Dr. Jules J. Lambiotte**
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j.j.lambiotte@larc.nasa.gov

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**Scientific and Technical Information (STI) Program Office (Lead Center for Agency's STI Program)** — This organization leads NASA's program for publishing, collecting, archiving, and disseminating NASA's scientific and technical information (STI) in addition to acquiring STI from more than 40 countries worldwide. The STI Program maintains the STI Database, which involves 3.5 million bibliographic citations and some full-text documents of STI. This activity involves not only skills in communication of information but also skills in technical support for information dissemination.

**George J. Roncaglia**
(757) 864-2374
g.j.roncaglia@larc.nasa.gov
Scientific information collection, publication, archival, and dissemination

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**EOSDIS Distributed Active Archive Center (DAAC)** — This activity includes data processing, archival, visualization, and distribution of Earth science data in the areas of radiation budget, clouds, aerosols, and tropospheric chemistry. Data comes from NASA's Earth Science Enterprise satellite missions and related activities.

**Richard S. McGinnis**
(757) 864-6893
r.s.mcginnis@larc.nasa.gov

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**Facility Systems Engineering** — This activity engineers, designs, constructs, and activates aerospace research facilities and equipment for aeronautical and associated institutional facilities for aeronautical and space research. Typical products include low and high speed wind tunnel facilities and equipment, including tunnel pressure shells and support systems, tunnel internals, automated control systems, devices to facilitate test measurements, process systems, model handling equipment, and calibration systems. Other typical products include test cells, simulation equipment, environmental test chambers, clean rooms, laboratories with ancillary systems and equipment, robotics systems, and other specialized research test apparatus/equipment.

**Dr. James R. Rooker**
(757) 864-6913
j.r.rooker@larc.nasa.gov

For research in structural finite-element modeling, dynamic structural analysis, heat transfer analysis of aeronautical and space research facilities

**Michael D. Mastaler**
(757) 864-6931
m.d.mastaler@larc.nasa.gov

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**Engineering Laboratory —** Physical and chemical analytical testing services are needed for the operation of research systems at Langley Research Center (LaRC) and are performed in the Engineering Laboratory. Analytical instrumentation is developed that will advance services at LaRC or will advance technology in aeronautics and space projects such as instrumentation for environmental controls; x-ray fluorescence spectroscopy for wear metal; agricultural and planetary geological analysis; radiation induced plasma generation, flow field and temperature visualization for wind tunnel models; and high temperature superconductive materials for magnetic levitation.

**Warren C. Kelliher**
(757) 864-4172
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**Fabrication Technology** — This technology area provides support in mechanical, electronics, and materials technology support for the Center's engineering and research organizations during the development, fabrication, and testing of research models, flight, and related ground support hardware, facility components, and laboratory test apparatus. The technology area administers contracts of major scope for services and tasks relative to the Center's research manufacturing requirements. Manufacturing standards and quality assurance procedures are established and implemented in accordance with Langley Research Center's Safety, Reliability, and Quality Assurance Program. This technology area determines requirements and initiates procurement of advanced manufacturing equipment and directs the development of fabrication processes applicable to unique materials and applications. It also formulates, establishes, and maintains a direct charge system for fabrication support.

**S. Stewart Harris, Jr.**
(757) 864-4539
s.s.harris@larc.nasa.gov

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## ATMOSPHERIC SCIENCES COMPETENCY

The goal of the Atmospheric Sciences Competency is to conduct research that will establish and maintain a solid foundation of technology embracing all of the disciplines associated with space and atmospheric sciences; and to provide a wellspring of ideas for advanced concepts. These programs include the following disciplines and specific research activities.

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**Stratospheric Aerosol and Gas Experiment (SAGE) —** Analysis and interpretation of atmospheric aerosol, ozone, nitrogen dioxide, and water vapor measured from SAGE I (1979-81) and SAGE II (1984-present) satellite instruments. Studies are directed toward developing global climatologies of these species and understanding the role these species play in atmospheric processes such as ozone depletion and global warming.

**Lamont R. Poole**
(757) 864-2689

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**Climate Research Program —** Theoretical, laboratory, and field investigations of the radiative properties of natural volcanic and man-made aerosols and assessment of their impact on regional and global climate. Remote and in-situ observations of cloud properties and radiation balance components and theoretical studies of the role played by clouds in the Earth's radiation balance.

**Patrick Minnis**
(757) 864-5671

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**Tropospheric Chemistry Research Program —** Assess and understand human impact on the regional-to-global-scale troposphere; define chemical and physical processes governing the global geochemical cycles from empirical and analytical modeling studies, laboratory measurements, technology developments, and field measurements; and exploit unique and critical roles that space observations can provide.

**James M. Hoell**
(757) 864-5826

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**Upper Atmosphere Research Program —** Expand the scientific understanding of the Earth's stratosphere and the ability to assess potential threats to the upper atmosphere. Includes developing empirical and theoretical models, formulating new instruments and techniques, performing laboratory and field measurements, and performing data analysis and interpretation studies.

**William L. Grose**
(757) 864-5820

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**Clouds and the Earth's Radiant System (CERES) —** Analysis of measurements from instruments on satellites that provide data on clouds and the Earth's radiation budget for assessing climatic impact of human activities and natural phenomena as well as a better understanding of all climatic parameters, in particular, the radiation budget components on a global scale.

**Bruce R. Barkstrom**
(757) 864-5676

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**Surface Radiation Budget Climatology Program —** Analysis of a long-term global time series of satellite measurements to estimate the surface and top-of-atmosphere solar and thermal infrared energy fluxes; comparison of these estimations to long-term surface and satellite measurements; assessment of balance and variability of these energy fluxes to processes in the atmosphere and at the surface toward understanding climate and climate variability on local to global scales.

**Paul W. Stackhouse, Jr.**
(757) 864-5368

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**Halogen Occultation Experiment (HALOE) —** Analysis and interpretation of measurements from this experiment on the Upper Atmosphere Research Satellite to improve understanding of stratospheric ozone depletion, particularly the impact of chlorofluoromethanes on ozone by analyzing global vertical profile data of O3, HCl, CH4, H2O, NO, NO2, and HF.

**John G. Wells**
(757) 864-1859

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**Global Biogeochemical Cycling —** Theoretical and field investigations of the biogeochemical cycling of atmospheric gases, with particular emphasis on the global budgets of oxygen, nitrogen, and carbon dioxide to better understand global change. Field measurements include studies of biogenic emissions of atmospheric gases from the soil and oceans and gases produced and released to the atmosphere during biomass burning, i. e., the burning of the world's forests and grasslands.

**Joel S. Levine**
(757) 864-5692

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**Transportation Systems —** Future space vehicle concept development, operations, research, and computer-aided design.

**Charles H. Eldred**
(757) 864-8211

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**Spacecraft System Studies —** Spacecraft concept development studies for Global Change science missions; large Earth orbiting spacecraft and platform systems studies; spacecraft subsystem analyses, performance, and technology assessments; mission design; and computer-aided design and simulations.

**Richard A. Russell**
(757) 864-1935

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# George C. Marshall Space Flight Center

## MISSION

The Marshall Space Flight Center offers opportunities for original work in many areas of physical sciences, mathematics, and engineering. Before preparing your proposal, prior discussion with a Center researcher is recommended. In general, Marshall advisers are interested in collaborative efforts with students and their university advisers and will look favorably on proposals that indicate that research time will be spent onsite at the Center.

## PROGRAM ADMINISTRATOR

Dr. James F. Dowdy
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jim.dowdy@msfc.nasa.gov
(Federal Express Address: Building 4200/Room 208

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## SAFETY AND MISSION ASSURANCE OFFICE

**Reliability Engineering —** Research and analysis are conducted to gain an understanding of complex physics of failure mechanisms with the Space Shuttle Main Engine. The use of statistical models, failure mode and effects analysis, and analysis of failure and anomaly reports, as well as applicable generic data, contribute significantly toward the research efforts.

**F. Safie**
(256) 544-5278

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**Quality Assurance Office —** Research is performed in areas dealing with software quality control, nondestructive evaluation (e.g., thermography, computed tomography), critical process controls, workmanship standards for state-of-the-art integrated circuit packages used in electronic fabrication, and assessment of critical characteristics in inspection with respect to control of critical items.

**R. Mize**
(256) 544-2485

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**Systems Safety Engineering —** Opportunities exist for research in the development and implementation of quantitative and qualitative techniques directed at the identification, evaluation, and control of hazards associated with complex space systems. This includes probabilistic risk assessment, fault tree analysis and applications, interactive hazard information tracking and closure systems, and the identification of conceptual approaches to establishing mission levels and requirements for various types of space missions.

**E. Kiessling**
(256) 544-7421

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## PROPULSION LABORATORY

**Propulsion Research & Technology Division —** Research and development of advanced propulsion systems and revolutionary technologies that will open up space to ambitious manned and unmanned exploration. A broad range of challenging projects are underway to achieve dramatic reductions in launch costs, routine transportation between Earth and orbit, rapid travel throughout the solar system and precursor missions to the stars. Activities focus on proof of concept experiments and flight tests to demonstrate new combustion techniques, laser-propelled launch systems, combined rocket/ramjet/scramjet engines, electric propulsion systems, magnetohydrodynamic thrust augmentation, solar thermal upper stages, nuclear thermal rockets, and interplanetary space drives using energy from nuclear fission, fusion or antimatter annihilation. Efforts are also being initiated to investigate phenomena at the boundaries of known physics that could lead to exploitation of vacuum energy, manipulation of space-time curvature and hyper-fast interstellar travel.

**G. Schmidt**
(256) 544-6055

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**Propulsion Systems Division —** Research and development of liquid rocket engines, solid motors and reaction control systems. There are activities in solid and liquid propellant combustion, performance prediction, combustion stability, engine risk management, launch and space vehicle propellant, and pressurization systems. Activities include prediction, analysis, and design of propulsion systems, subsystems, components and launch vehicles, and establishing test, integration, and verification requirements for flight and test bed propulsion systems.

**H. Pratt**
(256) 544-7069

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**Propulsion Design Division —** Activities involve research and development of mechanical subsystems such as propulsion feedlines, turbomachinery, combustion devices, thrust vector control, auxiliary propulsion, valves, actuators, controls, mechanisms, and environmental control and life support hardware. Another area of interest is establishing test, integration, and verification requirements for mechanical elements.

**T. Ezell**
(256) 544-3620

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**Test Division —** Activities include experimental research and development testing of propulsion systems, subsystems, and components for space systems hardware. Current areas of interest specifically relate to automated test control systems. A continuing interest exists for new and advanced instrumentation techniques.

**C. P. Jones**
(256) 544-5716

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## STRUCTURES AND DYNAMICS LABORATORY

**Experimental Fluid Dynamics —** Opportunities to develop and apply state-of-the-art experimental fluid dynamic methods to study application oriented flow problems. Areas of expertise include external aerodynamics, rotating machinery fluid dynamics, nozzle performance testing, low density environment testing, solid rocket motor internal flow environments, injector performance testing, and many other fields involving fluid flow. Research is needed in all of the above areas, as well as data analysis techniques and unique diagnostic systems development.

**W. Bordelon**
(256) 544-1579

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**Structural Dynamics —** Research and development in aerostructural modeling, vibration analysis, and load predictions using simulation of all environments, including propulsion, control, aerodynamics, and atmosphere. Probabilistic, as well as deterministic, approaches are used on SGI workstations and CRAY computers to simulate flight environments and obtain loads data on launch vehicles and propulsion hardware. Enhanced structural dynamic analysis techniques are pursued.

**J. Brunty**
(256) 544-1489

**J. McBride**
(256) 544-1523

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**Thermal Analysis/Liquid Propulsion Systems** — Opportunities for research exist in thermal analysis of liquid propulsion system components, including integrated thermal/structural analysis of turbine section and rotating components in high-pressure turbomachinery. Analytical results may be correlated to ground test data.

**B. Tiller**
(256) 544-4695

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**Thermal Analysis/Solid Rocket Motor** — Opportunities are available for research in thermal modeling and analysis of solid rocket motor thermal protection systems. Specific areas include the modeling of ablation processes involving a variety of material surfaces and the determination of heat transfer coefficients in radiative, erosive, and chemically reactive environments.

**K. McCoy**
(256) 544-7211

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**Thermal Analysis/Material Science Furnace Design** — Opportunities are available for research in the areas of thermal modeling, analysis, and design concepts for advanced materials science furnaces operating in a microgravity environment. Specific areas of interest may include integrated thermal/fluid modeling of samples during processing, advanced quench concepts, containerless processing, advanced sample heating technologies, and thermal management of processed samples.

**J. Owen**
(256) 544-7213

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**Structural Design Optimization/ Synthesis** — In view of the need for lighter, stiffer, and stronger launch and space vehicle structures, new ways of designing structural systems are being sought. Research on the synergistic effects of assembly of structurally optimized elements and components is needed. Efficient and effective design methods and tools using numerical optimization, trajectory analysis, thermal analysis, loads, stress environments, and other critical criteria are needed.

**D. Ford**
(256) 544-2454

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**Structural Assessment/Structural Analysis** — Opportunities exist for research in strength, stability, fatigue, and fracture mechanics analyses. Computationally intensive methods such as finite and boundary element analyses are used extensively. Practical enhancement methods are sought such as solution adaptive finite element modeling techniques. Technology improvement in analysis and computational methods which lead to development of practical engineering tools are encouraged. The CRAY computer is available for analytical analysis in conjunction with workstations.

**G. Faile**
(256) 544-7195

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**Vibroacoustics** — Mechanically and acoustically induced random vibration and test criteria and response loads analytically derived using advanced computer techniques. Vibration, acoustic, and transient data from engine static firing and Space Shuttle flights are analyzed and categorized. Research opportunities include improved vibroacoustic environment prediction methods, high frequency vibration data analysis techniques, and microgravity characterization.

**J. McBride**
(256) 544-1523

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**Fluid Dynamics Analysis** — Opportunities to develop and apply state-of-the-art computational fluid dynamic (CFD) methods to solve three-dimensional highly turbulent flows for compressible and incompressible, and reacting fluid states, and to provide benchmark CFD comparisons to establish code quality for subsequent application. Research is needed to assess significant aspects of the computational algorithms, grid generation, chemistry and turbulence modeling, code efficiency, and stability and solution visualization.

**R. Garcia**
(256) 544-4974

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**Guidance and Control Systems —** Opportunities for research exist in guidance and control systems analysis and design for launch vehicles, upper stages, various spacecraft, and a variety of space systems. Includes trajectories, orbital mechanics, attitude control, guidance, navigation, automated rendezvous and capture, fine pointing control, microgravity vibration isolation, active optics control, tethered system dynamics and control, POGO stabilization, thermal/process control, and turbomachinery rotordynamic analysis and stabilization.

**S. Ryan**
(256) 544-1467

**J. Hanson**
(256) 544-2239

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## MATERIALS AND PROCESSES LABORATORY

**Space Environmental Effects on Materials —** Evaluation of material is accomplished in simulated space environments involving vacuum, temperature, electron/proton and UV irradiation, atomic oxygen, and *plasma.* The effects of outgassing products of materials on weight loss, strength loss, surface properties, and redeposition and condensation on other items are being studied. Studies involving lubrication and surface physics of bearings in space and in rocket propulsion components are also being conducted. Research and development in new nondestructive evaluation (NDE) methods/processes and instrumentation are encouraged.

**M. R. Carruth**
(256) 544-7647

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**Metallic Materials —** Development of advanced materials for special applications in space propulsion systems is ongoing. The materials include aluminum, lithium, metal matrix composites and hydrogen resistant alloys. The effect of high-pressure, high temperature hydrogen on metals is an area of special emphasis. Research in microstructural analysis methods is being accomplished in support of failure analysis and materials characterization programs. Methods are being developed for quantitatively determining the state of corrosion, stress corrosion, and hydrogen embrittlement of alloys. Several development efforts are in progress relative to metals processing, including advanced welding methods, intelligent processing, robotics and sensor development.

**P. M. Munafo**
(256) 544-2566

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**Nonmetallic Materials Research —** Opportunities exist to develop and evaluate various materials for application in adhesives, elastomers, insulators, composite matrices, and molding and extrusion compounds for use in spacecraft hardware and in special environments. Composites utilizing carbon-carbon, carbon-resin, and ceramic matrix are being developed for applications to reduce mass or for high-temperature applications in rocket engines, structures, and leading edges. Research and technology efforts are underway in composite material fabrication, testing, and qualification for flight hardware application including automated filament winding and tape laying, pultrusion, tape wrapping, fiber placement, and hand lay-up. Additional opportunities exist for the development, application, and evaluation of cryogenic and high temperature thermal protection materials used in association with both liquid and solid propellant rocket motors. Also, use of computer aided engineering for process development and optimization including kinematics simulations.

**R. Clinton**
(256) 544-2682

## ASTRIONICS LABORATORY

**Electrical Systems —** Activities include development of photovoltaic array systems, battery technology and application, and electrical power system automation. Research is conducted in improved photovoltaic cell design and testing. Onsite resources include a photovoltaic test laboratory for simulation of on-orbit conditions. Research and application of electrochemistry is utilized to improve space flight batteries with life cycle testing and destructive physical analysis. Artificial intelligence approaches are used to support electrical power system automation.

**R. Bechtel**
(256) 544-3294

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**Electronics and Sensors —** Research, design, and development of activities are conducted on electronic control systems and measurement sensors for the guidance, navigation, and control of space vehicles. Subjects addressed are sensors, transducers, control actuators, reaction wheels, and pointing systems.

**J. Zimmerman**
(256) 544-3458

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**Optical Systems —** Opportunities exist for research, development, and application of technology in the following areas: coherent lidar systems (both gas and solid state technologies) target and detector calibration, transmitter evaluation signal processing atmospheric propagation and system modeling; video/film camera systems, including imaging systems development fiber optics video compression, radiometry, film camera and video system evaluation; and optical design, fabrication and testing including stray light analysis and testing, performance analysis, coating metrology, precision engineering and binary optics.

**J. Bilbro**
(256) 544-3467

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**Audio Systems —** Design, development, and evaluation of flight audio communications systems are performed in support of ongoing and future programs. Specific areas of interest include digital signal processing and encoding techniques, voice synthesis and recognition, and the effect on background noise on intelligibility.

**P. Clark**
(256) 544-3661

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**Communications Systems —** Test facilities are available to pursue research and development of antenna components and systems. These facilities include a fully automated kilometer pattern test range and a shielded anechoic chamber with 3.7 meter diameter quiet zone and supporting test equipment operating up to 60 Ghz. Other areas of interest include high-power, solid-state transmitters and spread spectrum receivers.

**L. Bell**
(256) 544-3678

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**Software Systems —** An area of high interest is the automatic generation of digital computer code from structured requirements. An area of particular interest is definition of a set of integrated computer aided support tools for software development from requirements phase through validation for embedded computer systems. Another target area of research and development is artificial intelligence techniques and tools to aid in fault diagnosis, load management, and scheduling for flight systems and subsystems.

**R. Stevens**
(256) 544-3728

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**Battery Cell Analysis —** Opportunities exist for research into the development of chemical and electrochemical techniques for analysis of aerospace battery cells. These include the modification of analytical techniques to minimize the amount of chemical waste produced and the development of electrochemical impedance spectroscopy as a tool in cell analysis. An important task in the latter is the development of an electrochemical model to be used in interpretation of spectra.

**D. H. Burns**
(256) 544-4807

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## SYSTEMS ANALYSIS AND INTEGRATION LABORATORIES

**Configuration Management —** Configuration management is an essential component of any successful engineering activity. Marshall projects tend to be both large and complex as well as small with short durations, requiring the efforts of teams of both NASA and contractor engineers. The level of control required by space flight makes configuration management a critical activity. Automated tools and improved methods are continually sought.

**B. Zagrodzky**
(256) 544-3293

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**Systems and Components Test and Simulation** — Opportunities exist for the development, qualification, integration, and flight acceptance testing of space vehicles, payloads, and experiments. Thermal vacuum testing is conducted in a variety of chambers with capabilities to 1X10- 7 torr pressure and temperature ranges from $-170^{o}$C to $+204^{o}$C. Facilities exist to calibrate X-ray payloads and scientific instruments utilizing a 518-meter evacuated guide tube.

**R. Stephens**
(256) 544-1336

**C. Reily**
(256) 544-1298

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## SPACE SCIENCES LABORATORY

**X-ray Astronomy** — Experimental, observational, and theoretical research is conducted in x-ray astronomy and high-energy astrophysics. The experimental program concentrates on development of replicated x-ray optics, polarimeters, and hard-x-ray imaging detectors operating from 1 keV to above 100 keV using microscrip and liquid-xenon technologies. Observational and theoretical specialties comprise the study of compact objects (neutron stars and black holes), cooling flows in clusters of galaxies, and astrophysics of high-temperature plasmas. Opportunities include participation in balloon flights of sensors, AXAF and other satellites, theoretical studies of physical processes in high-temperature astrophysical plasmas, and observations of clusters of galaxies and the Sunyaev-Zeldovich effect.

**M. C. Weisskopf**
(256) 544-7740

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**Biophysics** — An opportunity exists to conduct research in the separation and purification of biological cells and proteins to develop a basic understanding of the separation phenomenon. The proposed research should include analysis of the fundamental behavior of a separation process by theoretical and/or experimental methods. A second activity involves laboratory and space experiments in protein crystal growth. High quality single crystals are required to obtain the three-dimensional structure of the proteins, and Shuttle space experiments confirm the advantages of the microgravity environment. Projects include experiments to define improved crystallization conditions and the analysis of crystals by X-ray diffraction and factors that affect the crystal growth process and quality of crystals obtained.

**M. Pusey**
(256) 544-7823

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**Semiconductor Crystal Growth and Characterization —** Theoretical and experimental research is conducted on the effects of gravity on the crystal growth of semiconductors including model systems. Both the preparation and the characterization of materials are important. The areas of research include solid-state physics, chemistry, surface physics, solidification phenomena, fluid modeling, analysis of crystal growth, and characterization techniques. The well-equipped laboratory includes directional solidification and vapor growth apparatus including magnetic damping to five Tesla; extensive sample preparation facilities; and optical, x-ray, electronic, and electron-microscopic characterization equipment.

**F. Szofran**
(256) 544-7777

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**Microgravity Solidification: Contained Solidification of Metals and Alloys —** Buoyancy driven convection and sedimentation in the melt during metal and alloy solidification strongly influence the microstructure and thus important physical properties of the solid product. Also, under normal gravity, convection and sedimentation can mask the fundamentals of solidification that must be understood to allow the precise control of microstructure that can tailor materials properties. Current flight and ground experiments study phenomena such as dendritic growth, particle pushing and engulfment by solidifying interfaces, formation of eutectic and monotectic composite structures, and the transition from planar to cellular growth (morphological instability). Better experimental and theoretical methods are needed. Theory for all of the above mention processes must be reconciled with new experimental data. Experimental methods are being improved by such techniques as utilizing solid / liquid interfacial Seebeck measurements for undercooling, and X-ray transmission microscopy for real-time imaging of solidifying microstructure and solute concentration in the liquid.

**P. A. Curreri**
(256) 544-7763

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**Gamma Ray Astronomy —** Gamma ray astronomy uses space-borne and balloon-borne experiments to detect hard x-rays and gamma-rays above 20 keV. Most of the present research uses data from the Burst and Transient Source Experiment (BATSE) on the Compton Gamma Ray Observatory, although data from other spacecraft are also used. The primary astrophysical sources studied include gamma-ray bursts, galactic jets, black hole systems, accreting pulsars, solar flares, as well as the study of variability and spectra of other sources. Opportunities for participation in the development of a new generation of instruments for future gamma-ray astronomy experiments are also possible.

**G. Fishman**
(256) 544-7691

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**Space Plasma and Upper Atmospheric Physics —** We seek to better understand, and ultimately to predict, the flow of matter, momentum and energy through the region in which the Sun-Earth connection is made: the Earth's magnetosphere and ionosphere. We further seek to better understand basic physical processes that effect the operation of spacecraft in space and that are important in astrophysical plasmas; for example cometary, planetary, and stellar upper atmospheres. Plasma and gas dynamic processes are studied by means of in situ plasma measurements, and by remote optical and electromagnetic sensing of the constituent plasmas and gases. Activities include design, development, and calibration of flight instrumentation, with analysis and interpretation of the resulting data in terms of physical models.

**P. Craven**
(256) 544-7639

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**Solar Physics —** The influence of the magnetic field on the development and evolution of solar atmospheric structure, from the photosphere to the outer heliosphere, is studied. The primary data are vector magnetograms obtained at Marshall's Solar Observatory which are supplemented by data from the Yohkoh, SoHO, Ulysses, TRACE, and the GONG programs. The observations are complemented by theoretical studies to characterize the nonpotential nature of solar magnetic fields. This includes the development of MHD (magnetohydrodynamic) codes designed to simulate both coronal and large-scale interplanetary phenomena. Instrument development programs in optical polarimetry, grazing, and normal incidence X-ray optics, and imaging detectors for the X-ray and UV spectral regions are being pursued.

**D. Hathaway**
(256) 544-7610

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**Cosmic Ray Research —** Cosmic ray research at MSFC emphasizes the study of the chemical composition and energy spectra of cosmic ray nuclei above $10^{12}$ eV(TeV). Study of the interactions of heavy cosmic ray nuclei are also carried out to determine the behavior of nucleus interactions and to search for evidence of new states of nuclear matter. The research involves experiments with emulsion chambers and with electronic counters, exposed on balloons at about 40 kilometers altitude for up to two weeks. Research includes laboratory work, data analysis, particle cascade calculations, and calibrations of instruments with particle accelerators.

**T. Parnell**
(256) 544-7690

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**Astrobiology —** Astrobiology is the scientific study of the origin, distribution, and destiny of life in the universe, exploring the spatial, temporal, physical and environmental limits of life on Earth. The analogues developed may shape future space instrumentation and missions searching for evidence of extant or extinct life elsewhere in the Cosmos. Astrobiology also seeks to locate other planets and bodies in the Universe that may presently, or previously, been capable of supporting biology. Astrobiology seeks answers to the fundamental question – Is Life a Cosmic Imperative? Activities include the use of advanced Computer and Electron Microscopy tools to search for evidence of biomarkers and microfossils in ancient rocks and astromaterials, and obtain information concerning life on Mars, Buropa, Il, and comets. Viable microorganisms, permafrost and deep ice from Vostok, Antarctica are being actively explored as models of microbial life that might exist on other bodies of the solar system.

**R. Hoover**
(256) 544-7617

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## GLOBAL HYDROLOGY RESEARCH OFFICE

**Aerosol Backscatter and Doppler Wind Lidar Studies —** The research focuses on the assessment of global and regional patterns of aerosol backscatter, the calibration and characterization of Doppler Lidar systems, and the development of aircraft and space-based Lidars for the determination of regional and global winds relevant to contemporary issues in atmospheric research. Major experimental efforts have included ground-based and airborne Doppler lidar systems for backscatter and wind fields, intensive field campaigns, and a host of supporting aerosol sensors. Laboratory facilities exist for detailed calibration of short-focal length lidars, and for analysis of the optical properties of artificially generated aerosols resembling those found in nature. A multi-agency program, which has developed and is flying an airborne Doppler Lidar (MACAWS), will provide a wealth of unique measurement opportunities to support this research. Additional opportunities will be available in the development of lidar technologies for space-based flight.

**M. J. Kavaya**
(256) 922-5803

**J. Rothermel**
(256) 922-5965

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**Radar and Hydrometeorology Studies —** This research is directed towards understanding precipitation processes and their relation to the larger scale environmental forcing. Cloud microphysics, precipitation processes, storm kinematics, and morphology studies are conducted using ground-based and airborne research data acquired during field campaigns. Ancillary data from satellite and airborne microwave and imaging remote sensor data are used to further describe the convective processes. Data collected from the operational National Weather Service WSR88-D (NEXRAD) network are used to develop climatological rainfall estimates and water budgets to study the interannual variability of rainfall and its relation to changes in the synoptic and general circulation.

This research will lead to improved understanding of precipitation processes and algorithms developed for new satellite sensor suites.

**S. Goodman**
(256) 922-5891

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**Hydrometeorology/Land Surface Interface —** Earth's surface characteristics and their linkages to the atmosphere and hydrologic cycles are being analyzed and modeled using remotely sensed data. Measurements from satellite and aircraft sensors, in conjunction with *in situ* measurements, are used to study spatial and spectral resolution and temporal variability effects on determination of land surface energy fluxes, hydrometeorological characteristics, and biophysical components. The affects of spatial and temporal scale on land surface interface processes is assessed using mesoscale hydrometeorological and Global Circulation Models. Geographic information systems play an important research role in integrating and modeling remote sensing and ancillary data for analysis of the spatial and temporal dynamics of land surface hydrometeorological interactions.

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**Global Passive Microwave Studies —** The Defense Satellite Meteorological Program has launched a series of satellites with passive microwave sensors. These instruments (Special Sensor Microwave Imager, Special Sensor Microwave Temperature-1 and Special Sensor Microwave Temperature- 2) are used to detect and measure atmospheric temperature and moisture profiles, bulk atmospheric water vapor and cloud liquid water amounts, precipitation, and land surface temperature and type. Future research in the usage of one or a combination of these data sets for global multi-year or seasonal assessments of hydrometeorological parameters is desired.

**M. Goodman**
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**Atmospheric Electricity Studies —** The research is directed toward understanding the physical processes leading to the generation of electrical energy within thunderstorms, developing global lightning climatologies, and understanding the global electric circuit. Modeling, analytic, and observational approaches are used in these studies. Particular emphasis is placed on ground-, aircraft-, and satellite-based optical sensors to study the distribution and variability of global lightning activity. The recently launched Optical Transient Detector and future EOS instruments will play a major role in this research.

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**H. Christian**
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**Microwave Measurements** — Acquisition and analysis of aircraft and satellite microwave radiometer measurements lead to further understanding of the microphysical processes of precipitation systems and aid in monitoring global climate change. In this research, aircraft measurements are used to investigate the spatial and temporal structure of precipitation systems, improve inversion techniques for precipitation estimation, for the polarametric retrieval of surface wind velocity over oceans, and for increasing the understanding of heating profiles in tropical atmospheres. Pioneering work with the multiyear MSU satellite data sets are used for global temperature and precipitation studies.

**R. Spencer**
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**Atmospheric Chemistry** — Measurements of trace species and temperature in the upper troposphere, stratosphere, and mesosphere have been made from the Space Shuttle and other space platforms. These measurements are utilized to study the interactions between chemistry, dynamics, and radiation that are important in Earth's physical climate system. Especially important are the varying concentrations of stratospheric ozone that are determined by these interactions. This research effort utilizes space-based observations along with detailed models of the atmosphere to better understand the processes that determine stratospheric ozone, the interactions between the troposphere and stratosphere (including the role of water vapor), and the influence that human activities have on the atmosphere through the release of chemicals.

**T. Miller**
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**Climate Diagnostics and the Global Hydrologic Cycle** — Observational, numerical modeling, and analytical approaches are used to study the Earth's physical climate system. Diagnostic analyses of space-based observations are used to understand and validate models of global hydrologic cycle. Numerical models ranging in scope from atmospheric general circulation codes to mesoscale and cloud models are used to study water cycle processes and to quantify their role in climate. Sensitivity studies of climate models to surface boundary forcing, i.e., sea surface temperature, albedo and soil moisture anomalies are conducted. Simulations of remote sensors are used to understand how space-based observations can be best applied to studying the Earth as a system.

**F. Robertson**
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**The Role of Global Hydrology and Climate Variability in Human Ecology and Archeology** — The study of global hydrology and climate change is directed at understanding how changes in climate can be understood and potentially predicted. A study of past climates and cultures documents the effects of human/environmental interaction. Understanding how prehistoric cultures adapted to their environments through resource management and population dynamics is critical for societies today. Using remote sensing and GIS technology, this research investigates the adaptation techniques of prehistoric societies and compares the resultant success and failure of those techniques with the environmental and socioeconomic trends of current populations.

**T. Sever**
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**Water Vapor, Winds, and Climate Variability** — Water vapor is one of the most important greenhouse gases and is a key component of the Earth's hydrologic cycle, yet our inability to accurately measure it and monitor its variability around the globe is a limiting factor in understanding climate processes. This research focuses on the measurement and validation of atmospheric water as measured from satellites and the use of water vapor imagery for the determination of winds on a global and regional basis. Data from the U.S., Japanese, Chinese, and European satellites are used for regional and hemispheric analysis in support of climate studies.

**G. Jedlovec**
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**Retrieval and Use of Land Surface Temperature from Satellite Data** — This research focuses on retrieving land surface temperature from satellite radiance measurements for assimilation into numerical forecast models and for use in long-term climate monitoring. Evaporation of water from vegetation controls the physical temperature of the surface and can be monitored from satellite. The change in this temperature throughout the day is related to the flux of moisture from the surface, a parameter that is currently not well specified in regional numerical forecast models. The use of this new satellite information in the models has shown substantial improvement in the prediction of low-level temperature and moisture, cloud fields and subsequent precipitation.

**R. Suggs**
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## MISSIONS OPERATION LABORATORY

**Flight Operations —** The Mission Operations Laboratory performs functions contributing to the performance of science in space, particularly focusing on development of space science operations capabilities. Payload operations are integrated pre-mission and managed during the on-orbit execution in support of the science users. The operations control function includes command planning, control plans and procedures, and air-to-ground voice management. The data management function includes end-to-end flow analysis and management, requirements development for flight systems, and inter-center data requirements development. The mission planning function includes orbit analysis, mission timelining, flight design, and development of planning systems.

**T. Melton**
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**Training/Training Systems —** Training on payload operations is provided for the payload crew, payload flight controllers, and investigators using computer simulations, computer-aided training, mock-ups and/or engineering models. Continuous improvement requires that training methods and tools be assessed and updated on a periodic basis. This includes improving methods to acquire, organize and deliver training materials using recent improvements in multimedia technology and assistance from artificial intelligence technology. These updates are based on improved capabilities/technology, current information relative to pedagogy and lessons learned from previous training

**D. Underwood**
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**Gloria Hullett-Smith**
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**Ground Support Systems —** The Huntsville Operations Support Center is the ground facility that supports multi-project flight operations. The design and development function includes communications (voice, video, wideband data handling, and external information transfer), data acquisition and processing, payload and spacecraft commanding user work station data presentation, and facility support functions. Development includes prototyping new technologies to ensure state-of-the-art capabilities, with special emphasis on remote operations linking multiple ground facilities. The facility is managed and operated in support of project and user requirements.

**K. Cornett**
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**Human Factors Engineering/Human-Computer Interfaces/Virtual Reality —** Opportunities for research exist in human factors engineering (HFE), human-computer interfaces and interactions (HCI), and applied virtual reality (VR). New tools and techniques, especially computer-aided capabilities, need to be developed and/or validated to enhance/facilitate the application of HFE to the design, development, test, and evaluation of space systems. More effective HCI design methodologies and more efficient, distributed usability evaluation capabilities are needed for International Space Station experiment displays. Improved systems, components, software, and methodologies are need to apply VR to design analysis, operations development and support, and training.

**J. Hale**
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**Expert Systems —** New software methods are needed to automate and simplify increasingly complex ground support tasks associated with spacecraft and payload flight operations. Projects in the areas of automated analysis of engineering and operations telemetry, decision support, and trend analysis.

**M. McElyea**
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**Operations Analysis —** Operations analysis in support of flight and ground system development is performed using analytical techniques, mockups, and computer simulations. Flight control methods are developed and recommended based upon flight system requirements and objectives.

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# John C. Stennis Space Center

## MISSION

The John C. Stennis Space Center (SSC) is located about 25 miles northwest of Bay St. Louis on the Mississippi Coast. It is NASA's primary center for testing and flight certifying rocket propulsion systems for the Space Shuttle and future generations of space vehicles. Because of its important role in engine testing for more than three decades, Stennis Space Center has been designated NASA's Center of Excellence for rocket propulsion testing. Stennis is also NASA's lead center for rocket propulsion testing with total responsibility for conducting and/or managing all NASA propulsion test programs.

Stennis Space Center tests all Space Shuttle Main Engines. These high-performance, liquid-fueled engines provide most of the total impulse needed during the shuttle's eight and one-half-minute-flight to orbit. All shuttle main engines must pass a series of test firings at Stennis Space Center prior to being installed in the back of the orbiter.

Stennis Space Center is also NASA's lead center for commercial remote sensing within the Earth Science Enterprise. As such, SSC works to assist companies involved in environmental consulting, land use planning and natural resource management. Through these co-funded partnerships, companies use NASA-developed technology to develop information products.

The Earth System Science Office (ESSO) conducts research related to biological, chemical, geological and physical processes, as well as man's influence on these processes. This is done through the study of coastal processes (land and ocean) in support of NASA's Earth Science Enterprise.

SSC is unique in that NASA serves as host to 22 other federal and state agencies and university elements located at Stennis, including the U.S. Navy's world-class oceanographic and meteorological command.

## PROGRAM ADMINISTRATOR

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## PROPULSION TECHNOLOGY

**Thrust Measurement System —** Research opportunities exist to develop innovative thrust measurement systems. New thrust measurement systems for rocket engine testing need to offer greater flexibility and adaptability to changing test requirements. The current technology requires 18 months or more to design and fabricate thrust measurement systems. Requirements for thrust measurement systems include: ½% accuracy or better, ability to measure side loads during engine gimbling, and the ease of manufacture, installation and calibration. Three ranges of thrust measurement will be required for future programs: 20,000 to 100,000 pounds, 100,000 to 1,000,000 pounds, and 1,000,000 to 2,000,000 pounds.

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**Cryogenic Instrumentation and Cryogenic, High Pressure, and Ultrahigh Pressure Fluid Systems —** Over 40 tons of liquefied gases are used annually in the conduct of propulsion system testing at the Center. Instrumentation is needed to precisely measure mass flow of cryogen's starting at very low flow rates up to very high flow rates at pressures to 15,000 psi. Research, technology, and development opportunities exist in developing instruments to measure fluid properties at cryogenic conditions during ground testing of space propulsion systems. Both intrusive and non-intrusive sensors, but especially non-intrusive sensors, are desired.

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**Vehicle Health Management/Rocket Exhaust Plume Diagnostics —** A large body of UV-Visible emission spectrometry experimentation is being performed during the 30 or more tests conducted each year on the Space Shuttle Main Engine at SSC. Research opportunities are available to quantify failure and wear mechanisms, and related plume code validation. Related topics include combustion stability, mixture ratio, and thrust/power level. Exploratory studies have been done with emission/absorption spectroscopy, absorption resonance spectroscopy, and laser induced fluorescence. Only a relatively small portion of the electromagnetic spectrum has been investigated for use in propulsion system testing and exhaust plume diagnostics/vehicle health management.

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**Active and Passive Non-intrusive Remote Sensing of Propulsion Test Parameters —** The vast amount of propulsion system test data is collected via single channel, contact, intrusive sensors and instrumentation. Future propulsion system test techniques could employ passive non-intrusive remote sensors and active non-intrusive remote sensing test measurements over wide areas instead of at a few discrete points. Opportunities exist in temperature, pressure, stress, strain, position, vibration, shock, impact, and many other measured test parameters. The use of thermal infrared, ultraviolet, and multi-spectral sensors, imagers, and instruments is possible through the SSC sensor laboratory.

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**Ground Test Facilities Technology —** Ground test facilities seldom keep pace with propulsion system development programs partly because the facility is usually designed before the test requirements are known and because test facilities are usually extant and inflexible. An innovative approach to producing flexible, easily adaptable ground test facilities is highly desirable. Research opportunities are also available for developing uncertainty models of test facility systems. Additional opportunities exist in developing altitude simulation and self-pumping diffusers for large rocket propulsion system tests.

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**Advanced Propulsion Systems Testing —** Innovative techniques will be required to test propulsion systems such as advanced chemical engines, single-stage-to-orbit rocket plane components, nuclear thermal, nuclear electric, and hybrids rockets. With a shrinking budget and longer lead times to develop new propulsion systems, new approaches must be developed to test future propulsion systems. The solution may be some combination of computational-analytical technique, advanced sensors and instrumentation, predictive methodologies, and possibly sub-scale tests of aspects of the proposed technology.

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## TECHNOLOGY TRANSFER

**Marketing Strategies —** The design and development of marketing strategies to effectively promote and transfer a variety of technologies to the commercial sector. The design and development of methods/techniques to accurately capture economic impact of technology transfer initiatives.

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## EARTH OBSERVATIONS RESEARCH

**Remote Sensing and Plant Physiological Ecology —** The detection of plant radiative responses to growth conditions remains a major goal in remote sensing research. This is true particularly with respect to early detection of plant stress. We are interested in the continued study of leaf and canopy reflectance responses to various stress agents, and the development of techniques to enable the earliest possible detection of stress. This has involved the identification of narrow spectral bands in which reflectance is most strongly affected by various stress agents. We also are continually interested in basic influences on leaf radiative properties, and their relationships to leaf chemical content and physiological processes, particularly photosynthesis.

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**Coastal Processes —** Focuses on interdisciplinary research related to biogeochemical cycles (biological - physical interactions) and coupling between land and ocean processes. Work includes algorithm development and image processing across multiple computer platforms.

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**Research Software —** Emphasis on developing efficient software for the analysis and visualization of *in situ* and remotely sensed data for earth science research. Focus is on low-cost computer platforms.

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**Archeological/Anthropological Predictive Modeling —** Remotely sensed satellite and airborne data can be used to detect surface anomalies that may be representative of prehistoric and historic cultural remains. Sophisticated computer-analysis techniques have been developed to extract archeological/anthropological phenomena from the visible and non-visible portion of the electromagnetic spectrum. By combining remotely sensed and ancillary information into a database, accurate predictive models can be developed to isolate potential locations of archeological sites. Various cultural remains located in diverse environmental settings are examined to determine the spectral and spatial characteristics for the detection of archeological/anthropological features.

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**Paleoecological Research/Human Adaptations —** Focuses on the adaptation of human populations to coastal environments from prehistoric times to the present. Emphasizes interdisciplinary research to develop ecological baselines in coastal zones through the use of remotely sensed imagery, *in situ* field work and the modeling of human population dynamics. Utilizes cultural and biological data from dated archaeological sites to assess the subsistence and settlement patterns of different human societies in response to changing climatic and environmental conditions, particularly those events related to episodic fluctuations in sea level.

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## COMMERCIALIZATION

**Commercial Remote Sensing —** The Commercial Remote Sensing Program is designed to establish US preeminence in value-added information products derived from remote sensing and related information technologies. The program is accomplished by conducting collaborative research in application and advanced technology development projects with private firms, universities, and government agencies focused on the following areas: 1) satellite data acquisition, 2) data analysis/product generation, and 3) information distribution and product delivery.

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